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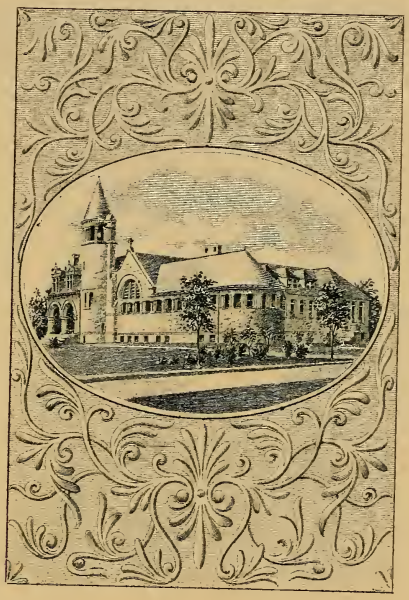

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# TREATISE

ON THE

# EYE,

## The MANNER and PHÆNOMENA of VISION.

IN TWO VOLUMES.

By WILLIAM PORTERFIELD, M.D.
Fellow of the Royal College of Physicians at *Edinburgh*.

VOL. II.

*Quid tam mirabile, quam particulam corporis quandam ita fabricatam esse, ut ejus opera animal sentiat procul positorum corporum figuram, positum, motum quemlibet, distantiam; idque etiam cum colorum varietate, quo distinctius ea dignoscceret? Nihil est, in quo manifestius Geometriæ artem Deus exercuerit.* HUGENII Cosmotheoros, p. 40.

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M,DCC,LIX.

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A

# TREATISE

ON THE

# EYE, the Manner and *Phænomena* of VISION.

## BOOK III.

## *Of Viſion.*

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### CHAP. IV.

*Containing ſome uſeful Reflections on the Motions of the Cryſtalline.*

SECT. I. HAVING, in the preceeding Chapter, explained the Change that is made in the Conformation of the Eye, by which we are enabled to ſee diſtinctly at different Diſtances, and the Uſe of the *Ligamentum Ciliare* in producing this Change; I ſhall now, by way of

Corollary, make a few obvious Reflections on what has been said on this Head. And,

*First*, If an Object be viewed distinctly at three different Distances from the Eye, the first of which may be the least Distance at which it can be viewed distinctly, the second double the first, and the third infinite; It is remarkable, that, by whatever means the Eye is supposed to be adapted to Distances, as great Alterations in the Conformation of the Eye are necessary for seeing the Object distinctly at the first and second Distances, whose Difference is but small, as at the second and third, whose Difference is infinite.

For Proof of this, let BCDE (PLATE I. *Fig.* 1.) be the *Axis* of the Eye infinitely produced, BC, BD, BE, the three Distances of the Object from the *Cornea* AB; and CA, DA, EA, three Rays falling upon any given Point of the *Cornea*, whereof EA is parallel to the *Axis*.

Now, to procure distinct Vision of the Points C, D, E, it is plain, that every one of the Rays CA, DA, EA, must be successively refracted to the same Point F upon the *Retina*, where it is cut by the Eye's *Axis*; Let us therefore suppose the Point F to be given, or the Length of the *Axis* BF to be immutable, and then the Quantity of the Refraction of each Ray must be varied by a Change of Figure in the Humours. And, because the Distance

Diſtance CD is ſuppoſed equal to CB or CA, the Angle CAD is equal to CDA, and conſequently to DAE; therefore, conceiving each Ray to come back again from the fixt Point F, to the Points C, D, E, ſucceſſively, the whole Quantity of its Refractions muſt firſt be leſſened by the Angle CAD, and then by the equal Angle DAE; and ſo the Changes of the Figures of the refracting Surfaces muſt be much the ſame when the Object is removed from C to D, as when it is removed from D to E. And the ſame thing may alſo be demonſtrated, when the refracting Surfaces keep their Figures immutably, and when Viſion is made diſtinct either by a Variation of the Place of the *Retina*, or by a Variation partly of the Place of the *Retina*, and partly of the Figures of the refracting Surfaces; as Mathematicians will eaſily find out by means of the *Theorems* by them demonſtrated, for finding the *Foci*, and therefore I ſhall not now waſte Time in demonſtrating it.

Hence, if ſhort-ſighted Perſons can read a ſmall Print diſtinctly at two different Diſtances, whereof the larger is but double the leſſer, which I believe moſt of them can do; it follows, that as great Alterations are made in their Eyes, as in perfect Eyes that can ſee diſtinctly at all intermediate Diſtances between Infinity, and the larger of thoſe two. And this

this is the Reaſon that a ſhort-ſighted Perſon can ſee diſtinctly at all Diſtances, with one ſingle Concave of a proper Figure; which otherwiſe muſt have been differently figured for different Diſtances; for the Cauſe of Short-ſightedneſs is not a want of Power to vary the Conformation of the Eye, but that the whole Quantity of Refractions is always too great for the Diſtance of the *Retina* from the *Cornea*.

§ 2. 2*dly*, Seeing that the natural State of the *Ligamentum Ciliare*, like that of all other Muſcles, is a State of Relaxation, it is eaſy to ſee, that the Cryſtalline muſt then be as near to the *Retina* as poſſible; whence it follows, that the Eye is naturally diſpoſed to ſee diſtinctly only diſtant Objects, and that that Diſpoſition whereby it is fitted for the diſtinct Viſion of near Objects, ariſing from the Contraction of this Ligament, is a State of Violence introduced at the Command of our Will:

For Confirmation of this, we might appeal to every one's Experience, who, we doubt not, will acknowledge, that when they are ſitting careleſsly, without attending to any Object, nothing at an ordinary Diſtance appears diſtinct, till a certain Effort be exerted, which will be remarkably greater in Proportion as the viſible Object is nearer: and this alſo agrees perfectly well with that neceſſary Connexion and Dependence

pendence that Habit and Cuſtom has eſtabliſhed betwixt the Motions of the Cryſtalline and certain correſponding Motions in the *Axes* of Viſion, which makes it impoſſible for us to direct our Eyes to any Object, without, at the ſame time, giving them that Diſpoſition that is neceſſary for ſeeing diſtinctly at that Diſtance; for, as our Eyes are naturally adapted for ſeeing diſtinctly only diſtant Objects; and as that Diſpoſition, whereby they are fitted to near Objects, is a State of Violence that requires an Effort, greater or ſmaller, as the Object is nearer or farther off; ſo the *Axes* of our Eyes are naturally parallel, which is the Direction proper for diſtant Objects; and when they are directed to a near Object, an Effort muſt be exerted, which alſo will be greater or ſmaller, in proportion as the Object is nearer or farther off; which Harmony and Agreement of Motions I eſteem a very great Confirmation of this Doctrine.

§ 3. 3*dly*, From what has been ſaid, we may clearly ſee, whence it is that our Eyes are ſo ſoon fatigued in looking to near Objects, which ſeldom happens when the Object is at any conſiderable Diſtance.

The Reaſon of this is obvious; for, when the Object is near, an Effort muſt be exerted, both by the Muſcles of our Eyes, for giving them the neceſſary Direction, and by the *Ligamentum*

*mentum Ciliare*, for giving them the neceſſary Conformation; which Effort being always greater in proportion as the Object is nearer, muſt be painful and laborious when the Object is very nigh; whence ariſes that Fatigue ſo often felt in looking long at near Objects; but when the Object is at any conſiderable Diſtance, ſo great an Effort is not required, eſpecially by the *Ligamentum Ciliare*, which, by ſome Experiments taken notice of above, is in my Eyes totally relaxed at the Diſtance of twenty ſeven Inches; whence at that, and all greater Diſtances, no Uneaſineſs can be felt, unleſs the Object be too bright and luminous, but what ariſes from the Direction of my Eyes, which is very inconſiderable; and therefore my Eyes are not ſoon fatigued in looking at an Object whoſe Diſtance is greater than twenty ſeven Inches; but when the Diſtance is leſs, they ſoon become ſenſible of an Uneaſineſs, which being proportionally greater as the Object is nearer, does ſoon require that the Eyes be relaxed; and this is the true Reaſon why none of us are able to look long to a very nigh b je&t.

§ 4. 4*thly*, From this alſo it is eaſy to underſtand, whence it comes to paſs, that, after the Eye has been very attentive in conſidering an Object at a certain determined Diſtance, it cannot preſently ſee another Object diſtinctly,

ly, at a greater or leſs Diſtance, though both Objects ſeems to touch one another, being nearly in the ſame Line.

This is ſo plain, that it needs no Proof or Illuſtration. For ſince the Conformation of the Eye muſt be fitted to the Diſtance, ſome Time will be required for finding out, by repeated Trials, that preciſe Diſpoſition which is neceſſary for ſeeing the Object at that Diſtance; and therefore it muſt appear confuſed and imperfect, till the Eye has exactly adapted itſelf to the Diſtance of the Object.

§ 5. *5thly*, This Motion of the Cryſtalline whereby our Eyes are accommodated to the Diſtance of Objects, being intirely voluntary and ſubjected to our Mind, which, being a wiſe Agent, wills its Motion, that Objects may not appear confuſed; it follows, that when by any other Means this Confuſion is taken off, the Mind will not then change the Conformation of our Eyes, unleſs there be ſomething elſe that can influence it to ſuch an Action: And this, after many Conjectures upon the Matter, I take to be the true Reaſon why the Eye is not adapted to the Diſtance of Objects viewed thro' a ſmall Hole made in a Card; and why, when viewed thro' ſeveral ſmall Holes whoſe Diſtance from each other does not exceed the Diameter

Diameter of the Pupil, they appear multiplied according to the Number of Holes; as has been obſerved above.

§ 6, *6thly*, Though this Motion of the Cryſtalline be ſubjected to our Mind, which, when the Object appears confuſed, changes its Situation, till by repeated Trials it finds out the preciſe Place it ought to poſſeſs for rendering our Sight as diſtinct as poſſible; and tho' this Confuſion in our Sight ſeems to be the only thing that ſhould influence our Mind to ſuch an Action; yet, by reaſon of a habitual or cuſtomary Connection that has grown up between the Motions of the Cryſtalline and certain correſponding Motions of the *Axes* of Viſion, theſe Motions come at laſt always to accompany one another, and that ſo neceſſarily as to make it impoſſible for us to ſeparate them by any Act of Volition.

Thus, when we view any Object at two Feet Diſtance, we not only accommodate our Eyes to that Diſtance, but we alſo move our Eyes, ſo as their *Axes* produced may meet in ſome Point of the Object; whence it comes to paſs, that theſe Motions, which at firſt had no neceſſary Connection or Dependence on each other, do in time come to cohere ſo cloſely as to make it impoſſible for us to direct our Eyes to an Object at two Feet Diſtance, without at the ſame time giving them that Diſpoſition that

that is neceſſary for ſeeing diſtinctly at that Diſtance; and what has been ſaid of Objects at two Feet Diſtance is alſo true of Objects at all other Diſtances within the Limits of diſtinct Viſion.

Whence it is eaſy to ſee, how the Eye may be made to change its Conformation, when an Object is viewed thro' a ſmall Hole made in a Card, tho' by Reaſon of the Smallneſs of the Hole, the Object appears always diſtinct, even when the Eye is not adapted to its Diſtance; for ſeeing the Motion of the Cryſtalline is, by Cuſtom and Habit, made to follow a correſponding Motion in the *Axes* of our Eyes, it follows, that by changing the Direction of our Eyes, the Eye muſt alſo, at the ſame time, accommodate itſelf to the Diſtance at which the optic *Axes* meet. It is for this Reaſon, that when a ſmall Body appears ſingle, when viewed thro' two ſmall Holes, whoſe Diſtance does not exceed the Diameter of the Pupil, it may be made to appear double; and if its Diſtance be ſuch as makes it appear double, the Diſtance betwixt the Appearances may be increaſed or diminiſhed, and all this only by changing the Direction of our Eyes.

§ 7. *7thly*, This Motion of the Cryſtalline by which our Eyes are adapted to the Diſtance of Objects, has its Limits, beyond

which it cannot go; whence it is, that none of us can see distinctly with the naked Eye, but within certain Limits, beyond which, if the Object be placed, it must appear confused more or less, as it is further removed from the Limits of distinct Vision.

These Limits are at different Distances, according to the Difference of People's Eyes; and very often in the same Man, both Eyes have not the same Limits, which is oftentimes of the same Use, as if the Limits of both Eyes were more distant from one another; for one may see an Object distinctly enough with only one Eye; but if the nearest Limits of one Eye is further off then the furthest of the other, then near Objects and distant Objects may be seen distinctly, but the intermediate ones must appear confused, which is a Case that is very apt to surprise such as despise or neglect Theory.

§ 8. 8*thly*, The *Ligamentum Ciliare* being the only Instrument by which our Eyes can be fitted for seeing distinctly at different Distances, it follows, that whatsoever affects the Oeconomy and Action of this Ligament, must also affect our Sight. Thus,

1*mo*, When it has become paralytic, no near Object will appear distinct; for an Example of which, see *Foresti Observationes*, *Lib.* xi. *Observ.* xxxvi. His Words are: *Gene-*

*rosus*

*neroſus vir et Dominus de Benthuyſen, anno* 1567, *menſe Maio, cùm ad eum accitus eſſem, conquerebatur ſe propiùs admota hebetiùs videre, longinqua verò optimè, &c.* And then, after telling us what he adviſed, ſays, *Quibus præſidiis tandem hoc vitium ceſſavit.* Nor are we to imagine, that the Caſe here was only a common *Viſus ſenilis:* For who is it that calls a Phyſician on ſuch an Occaſion? And as this Diſeaſe never yields to Medicine, it would not have been ſaid, *Quibus præſidiis tandem hoc vitium ceſſavit?*

2*do*, If this Ligament ſhould be convulſed, no diſtant Object will appear diſtinct. We have a beautiful Caſe to this Purpoſe recorded by TIMÆUS, which I ſhall alſo ſet down in the Author's own Words: *Studioſus quidem juvenis* (ſays he) *queritur, ſe menſæ aſſidentem legere poſſe etiam minutis literulis conſignata, non tamen internoſcere ſi qui hominum conclave ingrediuntur, donec proximius accedant, longiùs verò diſſita planè ſe non cernere: duravit iſte affectus jam ferè ſeſquiennio.* TIMÆI *Caſ. Medicinal. Lib.* i. *Caſ.* xxv. The Author indeed reſolves this Caſe into a Thickneſs and Muddineſs of the Humours of the Eye; but to me it ſeems more reaſonable it ſhould have been reſolved into a Contraction or Spaſm of the ciliary Proceſs; and if, by means of a concave Glaſs of a due Degree of Concavity, diſtant Objects could have been diſtinctly ſeen, (of which

which the Author has taken no Notice) this would have ſerved as a Proof of our Conjecture: For, on TIMÆUS's Suppoſition, as alſo on the Suppoſition that this Symptom proceeded from a certain Degree of Inſenſibility in the *Retina*, or immediate Organ of Sight, ſuch a Glaſs would have rendered the Sight yet more dark and confuſed than before.

From this we may poſſibly ſee why, in hyſteric and nervous Caſes, a certain Dimneſs of Sight is ſo frequently complained of; and in particular, why PISO's Matron was ſeized therewith for an Hour before her hyſteric and convulſive Paroxyſm, (PISO *de Colluv. Seroſ. Obſ.* XXV. *p. m.* 146.) For tho' this Symptom may ariſe from a Numbneſs or a certain Degree of Paralyſis and Inſenſibility in the optic Nerve; yet as certain it is, that it may alſo proceed from a Spaſm in this muſcular Proceſs; and ſeeing both are equally poſſible, I ſee no Reaſon for admitting the one and rejecting the other, without a very exact and impartial Examination of all the *Phænomena*, which in ſuch Caſes are commonly overlooked.

The great HIPPOCRATES, in many Parts of his Writings, has obſerved this Dimneſs of Sight to be the Attendant as well as the Harbinger of Spaſms and convulſive Motions; whence it ſeems reaſonable to ſuppoſe, that in many

many ſuch Caſes it ſhould alſo itſelf be occaſioned by a Spaſm in this Proceſs, whereby the Eye is diſqualified for ſeeing diſtinctly at an ordinary Diſtance. But all this I propoſe only by way of Conjecture, leaving it to be further examined by others, as Occaſion ſhall offer.

In the Caſe of ſome Poiſons, the Matter ſeems ſomewhat plainer; for as NICANDER, DIASCORIDES, and others have long ago obſerved, that this Dimneſs and Obſcurity of Sight, together with Spaſms and Convulſions of various Kinds, are the common Conſequences of Hemlock taken internally, ſo it ſeems pretty evident, from a Paſſage in ÆGINETA, that this does not proceed from any Degree of Inſenſibility in the Organ of Viſion, but from a Spaſm in this Proceſs. See *Lib.* v. *Cap.* xli. where, ſpeaking of this Subject, the following Words are very remarkable: "The Sight becomes ſo dim, that a Man is "wholly deprived of the Sight of *Diſtant* "Objects". But I muſt go on.

3*tio*, If this muſcular Proceſs ſhould be paralytic in one Side, and ſound in the other, the Cryſtalline muſt get an oblique Situation, when we look at near Objects, whence they will not appear diſtinct, unleſs the Eye be turned aſide from the Object. And,

4*to*,

4*to*, If this ſame Proceſs is convulſed on the one Side, while the other Side is healthful, the Cryſtalline will alſo get an oblique Situation, but not unleſs we view diſtant Objects, in which Caſe alſo it will be neceſſary to turn our Eye away from the Object it would view, that its Picture may fall on the *Retina* towards the *Axis* of the Eye, where it is moſt ſenſible. But,

5*to*, If in the one Side it ſhould be convulſed, whilſt it is paralytic in the oppoſite Side, the Cryſtalline will always have an oblique Poſition, at whatever Diſtance the Object may be placed; and therefore the *Strabiſmus* ariſing from this Cauſe, muſt be conſtant and uninterrupted; whereas, in the two former Caſes, it only takes Place in certain Circumſtances. But, for the better underſtanding what has been ſaid on this and the two immediately preceeding Heads, it may be proper to refer the Reader to what ſhall be ſaid afterwards on the Subject of the *Strabiſmus*, towards the End of this Volume; from which it will alſo appear, that in all theſe Obliquities of the Cryſtalline, the Object will not be ſeen in its proper Place, where it is ſeen with the other Eye, but will be thence tranſlated to ſome other Place, from which Tranſlation it muſt neceſſarily appear double.

6*to*,

6*to*, When this Ligament has become rigid and ſtiff, the Cryſtalline will have but very little Motion, whence the Limits of diſtinct Viſion will be very narrow: Thus it is with all thoſe who are much employed in any ſubtile Work, ſuch as Engravers, Jewellers, Watch-makers, Painters in Minature, *&c.* who are very apt to become ſhort-ſighted from their conſtant Application to ſmall Objects, which cannot be diſtinctly ſeen but at a very ſmall Diſtance; and therefore they are obliged, by the Contraction of this *Ligament*, to bring the Cryſtalline as near to the *Uvea* as poſſible; but all Muſcles that continue long in the ſame State become rigid and ſtiff, and loſe much of their Activity; and therefore, this *Ligament*, by its conſtant Contraction, muſt at laſt ſhrink, and have its Fibres ſhortened, which will keep the Cryſtalline fixed in that Situation, by which the Eye is diſqualified for ſeeing diſtant Objects diſtinctly. This has been obſerved by RAMAZZINI, *de Morbis Artificum*, *Cap.* xxvi. who therefore judiciouſly adviſes all ſuch, from time to time, to intermit their Work, and recreate their Eyes with a Diverſity of Objects, leſt they ſhould loſe their Mobility, and become ſhort-ſighted.

The Reverſe of this Diſeaſe happens to ſuch as are ſeldom employed in obſerving near Objects, but who from their Infancy have accuſtomed

cuſtomed themſelves to look much to diſtant Objects, ſuch as Hunters, Falconers, Sailors, *&c.* In thoſe this Ligament is much relaxed, by which they can ſee at a great Diſtance; but by reaſon they are ſo little accuſtomed to obſerve near Objects, it loſes much of its Faculty of Contraction, whence they cannot accommodate their Eyes to near Objects: And thus we ſee how the *Viſus ſenilis*, as well as the *Myopia*, may be acquired by Uſe and Cuſtom. But I muſt go on.

§ 9. 9*thly*, The *Ninth* and laſt Reflection I ſhall make on this Subject, ſhall reſpect the Cauſe of this Change of Conformation in our Eyes, which is either *efficient* or *final*.

As to the *efficient Cauſe*, it has been already demonſtrated, that this lies in the *Ligamentum Ciliare*, which being muſcular, does by its Contraction change the Situation of the Cryſtalline, according as Objects are nearer or further off. But, leſt it ſhould be imagined, that our Mind does not perſide over this Motion of the Cryſtalline, by reaſon we are ſo very little conſcious of its Influence, it muſt here be obſerved, that there are many other Motions that are no doubt voluntary and depending on our Mind, of which we are every bit as little conſcious.

No body denies but the Mind preſides over thoſe Muſcles which tune the Ear, and yet we

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are not conſcious of their acting. The Motions of the Eye-lids are alſo all voluntary, tho' we are often inſenſible of them, and even in many Caſes cannot, by any Act of Volition, hinder them to move in a particular Manner: Thus, when the Eyes are turned up or down, the Eye-lids always follow their Motion, and keep at the ſame Diſtance from the Pupil; and if a Body be haſtily moved towards our Eyes, they will ſhut without our being conſcious thereof: Neither is it in our Power to do otherwiſe, becauſe we have accuſtomed ourſelves to do ſo on the like Occaſions; for ſuch is the Power of Cuſtom and Habit, that many Actions which are no doubt voluntary, and proceed from our Mind, are in certain Circumſtances rendered ſo neceſſary, as to appear altogether mechanical and independent on our Wills; but it does not from thence follow, that our Mind is not concerned in ſuch Motions, but only that it has impoſed upon itſelf a Law, whereby it regulates and governs them to the greateſt Advantage. In all this there is nothing of intrinſical Neceſſity; the Mind is at abſolute Liberty to act as it pleaſes, but, being a wiſe Agent, it cannot chuſe but to act in Conformity to this Law, by reaſon of the Utility and Advantage that ariſes from his Way of acting: Thus the Ear is tuned to different Sounds, the Eye is accommodated to Objects at different Di-

ſtances, the Pupil is proportioned to the Intenſity and Weakneſs of Light, while at the ſame time we are not conſcious of our having done any Thing: And when theſe and ſuch like Motions have become neceſſary in certain Circumſtances, ſo as to render any other Motion impoſſible, this does not make them mechanical and independent on our Will, but only ſhews us, that the Mind, which at firſt always acted from a Principle of Intereſt, comes at length to be determined by Habit and Cuſtom, without examining how far ſuch Motions may be profitable or hurtful to us, or at leaſt without being ſenſible of any ſuch Examination: And this is the only Reaſon can be given why none of us are now able to move our Eyes differently, tho' when Children we were poſſeſſed of that Power: And with reſpect to the Eye-lids, the Caſe is exactly the ſame; for, tho' we are not now at Liberty to keep them open when any thing is haſtily moved towards our Eyes, yet that this proceeds intirely from Cuſtom, and not from any abſolute or mechanical Neceſſity in the Thing itſelf, is evident from this ſingle Conſideration, that ſome may be found who can keep them open, tho' the Organs ſubſervient to their Motions are the ſame as in other Men. Thus it was with the two *Roman* Gladiators taken notice of by PLEMPIUS (*Ophthalmogr. Lib.* i. *Cap.* ii.) who

who being of uncommon Fortitude and Courage, had not accuſtomed themſelves on every trifling Occaſion to ſhut their Eye-lids for the Defence of their Eyes, whence their Motions continued arbitrary in the ſtricteſt Senſe. Thus alſo it ſeems to have been with that excellent Philoſopher SOCRATES, who, in the Judgment of APOLLO, was the wiſeſt Man on Earth; and yet, for no better Reaſon than for to accuſtom himſelf to Patience, he was wont to ſtand for a whole Day like a Statue, without the leaſt Motion, not ſo much as of his Eyes or Eye-lids, (*Gell. Noct. Att. Lib.* ii. *Cap.* i.)

§ 10. But the Matter does not ſtop here, our Mind does not only preſide over the Motion of the Cryſtalline, and ſuch other Motions as are commonly ſaid to be voluntary, but there is good reaſon to ſuſpect, that it extends its Dominion and Influence even over all the *vital* and *natural Motions*.

Some very great Philoſophers, and particularly DES CARTES and his Followers, have been of Opinion, that our Mind always thinks, and yet this is, what we are often very little conſcious of; and if the Mind can think without our Knowledge, I ſee not why it may not alſo be allowed to exert its active Power in the Government of the *vital* and *natural*

*natural Motions*, without our Knowledge or Attention.

I know it has been alledged by LOCKE and others, That all the Thoughts and Operations of the Mind muſt neceſſarily be attended with Conſciouſneſs; from whence it may be argued, that the Mind is not concerned with theſe Motions, becauſe it is altogether inſenſible of its Influence. But, without determining how far the Thoughts and Operations of the Mind may or may not imply Conſciouſneſs, which is a metaphyſical Queſtion, I leave to be diſputed by thoſe who have better Thought of that Matter; it is ſufficient for my preſent Purpoſe to have ſhewn in a few of many Inſtances that might have been brought, that there are Motions unqueſtionably voluntary and depending on the Mind, which by Cuſtom and Habit have become ſo eaſy as to be performed without our Knowledge or Attention, and that ſo neceſſarily as to make it impoſſible for us, by any Effort of Mind, to hinder them from going on in their uſual Manner. And ſeeing every one's Experience and Obſervation may afford him many Inſtances of ſuch Motions as theſe, I would gladly know why the *vital* and *natural Motions* ſhould be eſteemed of a different Kind.

If any one ſhall look ſtedfaſtly at the Moon, the Index of a Clock, or any other Object moving

moving ſlowly, for ſome little Time, ſuppoſe half an Hour or an Hour, he will neither be conſcious of his having been ſenſible of the Motion of the Object, nor of his having willed the Motion of his Eyes that was neceſſary for to keep them fixed thereon; and yet that he was ſenſible of this Motion of the Object, is evident, becauſe his having been ſenſible of it was the only Cauſe that could determine him to move his Eyes and make them keep Pace with the moving Body; and that he willed the Motion of his Eyes tho' he cannot well be ſaid to have been conſcious of it, is evident, becauſe the moving Body, notwithſtanding its Motion, continued always to be ſeen diſtinctly, and conſequently had its Picture all the While in the Axis of the Eye where the *Retina* is moſt ſenſible. From this Inſtance alone we may ſee how Motions unqueſtionably voluntary may be performed by the Mind, tho', in a common Way of ſpeaking, at leaſt, we may neither be conſcious of its Volitions on which theſe Motions depend, nor of the Senſations or other moral Motives, that may have influenced our Mind to will theſe Motions; the Want of ſuch Conſciouſneſs is therefore no ſolid Objection to the *vital* and *natural Motions* being cauſed by our Mind.

I do not by this mean to ſay, what I find inſinuated by others, that inſenſible Senſations

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or *Stimuli*, that are not at all perceived, can any Way act as Motives, or influence our Mind in its Actions, or that the Mind may be abſolutely unconſcious of its own Volitions by which theſe Actions are executed; for this may be thought to imply a Contradiction, and I think it beſt to avoid, as much as may be, all metaphyſical Controverſies; all I would therefore ſay, and all that the preſent Argument requires I ſhould ſay, is, that as, in the Inſtance juſt now given of the Motion of our Eyes, we can neither, in a common Way of ſpeaking, be ſaid to have been conſcious of the Volitions of the Mind cauſing that Motion, nor of the Senſation of Motion in the Object influencing the Mind thereto, ſo in like Manner the *vital* and *natural Motions* may be owing to the Mind, tho' neither its Volitions nor the Senſations moving it thereto ſhould be attended with any remarkable Conſciouſneſs.

§ 11. That they cannot be accounted for from Mechaniſm alone, is very certain; for all the Hypotheſes that have hitherto been, or may hereafter be invented, for explaining thoſe Motions mechanically, do and muſt proceed upon the Suppoſition of the Poſſibility of a perpetual Motion.

By a perpetual Motion, I mean an uninterrupted Communication of the ſame Degree

Degree of Motion, from one Part of Matter to another, in a Circle, ſo as perpetually to return undiminiſhed upon the firſt Mover, which, in the preſent Conſtitution of Things, is repugnant to the Laws of Nature; for ſeeing *all Motions and Changes made in the Motions of Bodies are always proportional to the impreſſed moving Force;* and ſeeing all Motions on this Globe are performed in a reſiſting Fluid, *viz.* the Air, a conſiderable Quantity of the Motion muſt be ſpent in the Communication on this *Medium*; and conſequently it is impoſſible the ſame Quantity of Motion ſhould return undiminiſhed upon the firſt Mover, which is neceſſary towards a perpetual Motion. Moreover, the Nature of all material Organs is ſuch, that there is no avoiding a greater or leſſer Degree of Friction, tho' the Machine be formed according to the exacteſt Principles of Geometry and Mechanics, there being no perfect Congruity, nor exact Smoothneſs in Nature: And this alſo muſt very conſiderably diminiſh the communicated Force; ſo that on both theſe Accounts it is impoſſible there ſhould be a perpetual Motion, unleſs the communicated Force were ſo much greater than the generating Force, as to recompence the Diminution made herein by theſe Cauſes; ſo that the impreſſed Motion may return undiminiſhed to the firſt Mover: But that being contrary to the above mentioned,

ed Law of Motion, it is clear that the Motion muſt continually decreaſe, till it at laſt ſtop, and conſequently there can be no perpetual Motion in the preſent State of Things: *Liquet ex calculo mechanico*, ſays the learned Dr. CLARKE, in ROHAULT. *Phyſ. p.* 1. *cap.* 22. *ar.*86. *omnem de motu perpetuo quæſtionem eò redire, ut pondus inveniatur ſeipſo ponderoſius, vel vis elaſtica ſeipſâ fortior, quod eſt abſurdum**.

§ 12.

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* Having more than 20 Years ago, in the *Edinburgh Medical Eſſays, Vol.* iv. had Occaſion to make Uſe of this Argument, amongſt the others here mentioned, for proving that the vital and natural Motions may depend on the Mind, it gave me ſome Pleaſure to find that this Doctrine was pretty well received by many learned men. Amongſt others, the ingenious Dr. WHYTT alſo embraced it, and, about 6 or 7 Years ago, publiſhed a large Eſſay on that Subject; in which indeed he differs from me in ſome particulars, but in the main agrees with me, in making all the *vital* and *natural Motions*, as well as thoſe called *Voluntary*, to proceed from the Mind. But I could not help being ſomewhat ſurprized to find, that this learned Gentleman ſhould ſeem to think this Argument ſuch as cannot be depended on; for, tho' he acknowledges, that "*it* "*ſeems demonſtrative*;" yet, being an *Argument a priori*, he ſays, "as this Kind of Reaſoning is apt to render us too pre-"ſumptuous, and frequently betrays us into Error and Miſtakes, "we ſhall further endeavour to vindicate this Opinion from the "moſt plauſible Objections which may be brought againſt it, "and at the ſame time ſhow, by a Variety of Arguments *a* "*poſteriori*, chiefly of the analogical Kind, that the *vital*, as "well as the other *involuntary Motions* of Animals, are directly "owing to the immediate energy of the Mind or ſentient Prin-"ciple, *&c.*" (See WHYTT *on the Vital Motions, p.* 267.) And I was ſtill the more ſurprized, when I found this Argument made

§ 12. No body now-a-days, that underſtands any Thing of Nature and Philoſophy, can ſo much as imagine that any Animal, how abject ſoever, can be produced by Mechaniſm, without any active immaterial Cauſe; we all know there



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made uſe of by Himſelf in the very next Page, and the three following ones; for if he thought the Argument fallacious and apt to render us too preſumptuous, I could not ſo eaſily ſee why he ſhould have made Uſe of it. It is indeed true, he has put it in a different Dreſs, ſo as, to an unattentive Reader, it may appear a different Argument. But the Argument is the very ſame; and I believe no body that conſiders the Way in which he has ſtated it, will think that it has received any additional Strength in paſſing thro' his hands. He has alſo cloſed his Argument with the ſame Quotation from Dr. Clarke, that I have cloſed mine with. And indeed the whole Argument, as I have ſtated it, is nothing but a Comment or Explanation of this Quotation, a mere *mechanical Calcul*, which can never betray us into any Error or Miſtake. It is indeed true, that it is an Argument *a priori*: But what then? Do not all mechanical Writers aſſume the Laws of Motion, that have been eſtabliſhed by Experiments, or other certain Truths, and from thoſe, as Principles, argue *a priori* in deducing the Effects and Conſequences that proceed from them? Were this Kind of Reaſoning to be ſet aſide as fallacious, a great Part of Mechanics, and of the other Branches of Natural Philoſophy, and even of Sir Isaac Newton's Principles and Optics, behoved alſo to be ſet aſide, as being founded on this Way of Reaſoning. I am therefore ſo far from thinking this Argument fallacious, and not to be depended on, that I think it ſtrictly demonſtrative, and that all that either the Doctor or I, or any body elſe, have ſaid, or may ſay, on the vital and natural Motions, can perſuade no body that they proceed from the Mind, unleſs this Argument is allowed to demonſtrate, that they cannot proceed from Mechaniſm: And that it demonſtrates this, is evident, from its being agreeable to the Method of Philoſophizing,

there is nothing in the animal Machine but an Infinity of branching and winding Canals, filled with Liquors, of different Natures, going the ſame perpetual Round, which are no more capable of producing the wonderful Fabric of another

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zing, ſo often uſed by our great Philoſopher, and deſcribed by him in his *Optics*, *Query* 31. in the following Words:

"As in Mathematics, ſo in Natural Philoſophy, the Inveſtiga-
" tion of difficult Things by the Method of *Analyſis*, ought ever
" to preceed the Method of *Compoſition*. This *Analyſis* con-
" ſiſts in making Experiments and Obſervations, and in draw-
" ing general Concluſions from them by Induction, and admit-
" ting of no Objections againſt the Concluſions, but ſuch as are
" taken from Experiments, or other certain Truths. For Hy-
" potheſes are not to be regarded in Experimental Philoſophy;
" and altho' the arguing from Experiments and Obſervations by
" Induction be no Demonſtration of general Concluſions; yet
" it is the beſt Way of Arguing which the Nature of Things
" admits of, and may be looked upon as ſo much the ſtronger,
" by how much the Induction is more general; and if no Ex-
" ceptions occur from *Phænomena*, the Concluſion may be pro-
" nounced generally. But if at any time afterwards any Ex-
" ceptions ſhall occur from Experiments, it may then begin to be
" pronounced with ſuch Exceptions as occur. By this Way of
" *Analyſis* we may proceed from Compounds to Ingredients, and
" from Motions to Forces producing them, and in general from
" Effects to their Cauſes, and from particular Cauſes to more ge-
" neral ones, till the Argument end in the moſt general. This
" is the Method of *Analyſis*; and the *Syntheſis* conſiſts in aſſu-
" ming the Cauſes diſcovered and eſtabliſhed as Principles, and
" by them explaining the *Phænomena* proceeding from them,
" and proving the Explanations"

This is the Method of Philoſophizing laid down by this incomparable Philoſopher, and which he himſelf has followed with ſuch amazing Succeſs; and I know no Method equal to it, or more worthy to be purſued.

As

another Animal, than a Thing is of making itſelf. Beſides, in the Generation of an Animal, there is a Neceſſity that the Head, Heart, Nerves, Veins and Arteries, ſhould all be formed at the ſame Time; which can never be done by the Motion of any Fluid, what Way ſoever moved: For the Heart cannot move unleſs animal Spirits be ſent from the Head through the Nerves into it. The animal Spirits cannot be derived into the Heart, unleſs the Blood be ſqueezed by the Heart through the Arteries into the Brain; ſo that

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As for Arguments of the anological Kind, which the Doctor ſeems to depend more upon, theſe I have alſo made Uſe of; tho' it muſt be owned, that ſuch Arguments are vaſtly more fallacious. And indeed I know no Kind of Arguments that are more ſo, in the Way theſe analogical Arguments are commonly uſed; for tho' they are of great Uſe in many Caſes, yet if we are not very attentive, and take great Care to keep ourſelves within that wherein the Analogy conſiſts, which is ſometimes very difficult, and which few ſeem to be ſollicitous enough about, they are apt to deceive us, and lead us into Errors and Miſtakes: For Example, let it be ſuppoſed, that the acid Oil of Vitriol is found to be good in ſuch a Caſe; if from thence we conclude that the Spirit of Nitre or Vinegar may be uſed in the like Caſe, we may be deceived; for tho' the Argument may be juſtified, if we know with Certainty that the good Effect of the Oil of Vitriol is wholly owing to the Acidity of it; yet, if there be ſomething elſe beſides the Acidity of the Oil of Vitriol which produces the Good we deſire in the Caſe, which may be the Fact, for any thing we may know to the contrary, we miſtake that for Analogy which is not, and ſuffer our Underſtandings to be miſguided by a wrong Suppoſition of Analogy, where there is none. This Inſtance is ſufficient to ſhew how fallacious analogical Arguments are, and what Abuſes are committed therein.

that it is evident, that the Head and Heart, the Arteries, Veins and Nerves, muſt all be formed at the ſame Time, and not ſucceſſively, if the Animal is mechanically produced. But this is altogether impoſſible; for no Motion of any Fluid or Fluids, howſoever diſpoſed, can form all theſe at the ſame Inſtant: And we know all the internal mechanical Actions of Animals are performed by the Force of their circulating Fluids.

From theſe, and ſuch like Conſiderations, it is evident, that an Animal cannot be produced mechanically. This is too hard a Problem to be ſolved from ſo few *Data* as Matter and Motion; and it is doing Penance to read the wretched Accounts of the wiſeſt and moſt learned Phyſicians and Philoſophers on this Head: Read but DES CARTES, who by a bold, not to ſay impious Attempt, was the firſt ſince PROMETHEUS and DEMOCRITUS's Days, who endeavoured to make an Animal; I ſay, read but DES CARTES, and you will ſee how in every Step he contradicts the known Laws of Motion: And indeed the Manner after which he will have them generated, is as much above the Power and beyond the Laws of Mechaniſm, as the true and genuine Manner and Method of their Production is.

Seeing

Seeing then that the Formation of Animals does not depend on Mechaniſm, but on the powerful Influence and Operation of ſome immaterial Cauſe, whether of GOD himſelf, the Soul of the Animal, or of ſome other ſubordinate Being, ſome vital Principle, plaſtic Power, or *Archæus*, concerns not the preſent Queſtion: I ſay, ſeeing that Animals are not at firſt produced by Mechaniſm, but by ſome active immaterial Cauſe, why, after that, ſo great Concern ſhould be ſhewn to reduce all to mere Mechaniſm, and to exclude an intelligent and active Principle from having any Share in the Government of thoſe Motions on which Life depends; and why it ſhould be thought that theſe Motions ſhould never ſtand in need of New Impreſſions from ſome ſuch vital Principle as firſt ſet them a-going, I cannot ſo eaſily conceive.

If it ſhould be ſaid, that theſe Motions do not depend on Mechaniſm alone, but on Mechaniſm joined with certain active Powers or Forces, imprinted by the Author of Nature upon all the Bodies of this Univerſe, ſuch as are the Powers of Attraction and Repulſion, by which indeed the greateſt Part of the *Phænomena* of Nature are unqueſtionably produced; it is incumbent on thoſe who entertain this Opinion, to explain particularly how theſe Motions are thus continued by theſe active Principles, before they can expect we ſhould believe them.

them. Could one ſingle Inſtance be brought of any Motion that goes on perpetually in this Manner, without ſtanding in need of new Impreſſions from any active and intelligent Cauſe, there might be ſome more Pretence for this Hypotheſis; but as no ſuch Inſtance is to be found, I ſee no Neceſſity of having Recourſe to ſuch a Suppoſition, for explaining the vital and natural Motions.

§ 13. Is it not certain, that theſe Motions are powerfully influenced by the Paſſions of Fear, Grief, Joy, Rage, *&c.*? And does not this clearly ſhew their Dependence on the Mind? The learned Dr. CHEYNE (on the *Engliſh Malady*, *p.* 307.) gives the Caſe of Colonel TOWNSHEND, who, for ſome Time before his Death, could at Pleaſure ſuppreſs all the vital Motions, ſo as in all Reſpects to appear dead; and yet by an Effort, or ſome how, he could come to Life again, and reſtore theſe Motions. The Caſe is indeed ſingular, but not at all to be accounted for, without allowing the Mind to preſide over the vital Motions.

But this is not all; for in ſome Creatures the Motion of the Heart has been found ſo irregular, as to give Cauſe for eſteeming it altogether *arbitrary* in the common Acceptation of the Word. There is a remarkable Inſtance of this recorded by LISTER, which I ſhall ſet down in the Author's own Words: *Denique* (ſays he, ſpeaking of the *Cochlea*) *cor nudatum, et oculis, ut*

*ut hac ſectione fit, planè objectum, modo ſponte ad aliquam multa momenta, imo quadrantem horæ, pulſare deſiit; iterumque ſponte ſe ſtrenuè et celeriter movebat. Ut certiſſimum ſit, cordis motum, in id genus animalibus, etiam voluntarium eſſe, et non merè naturalem, ut in homine reliquiſque ſanguineis animalibus; ſed pro earum lubitu ad quodvis tempus ſiſti, aut moveri poſſe, &c.* See LISTER *de Cochleis et Limacibus, p.* 38.

All theſe Things being conſidered, it ſeems probable to me, that the Mind does not only preſide over thoſe Motions commonly called *Voluntary*, but that it is alſo conſtantly employed in the Government of all the *vital* and *natural* Motions, which of themſelves would ſoon ſtop, were it not for the Influence and Interpoſition of this active Principle. It ſeems to me further, that theſe Motions in the Beginning of Life are altogether *arbitrary*, in the common Acceptation of the Word, and that it is only from Uſe and Cuſtom that they have become ſo neceſſary as to make it impoſſible for us, by any Effort of Mind, to hinder them from going on in their uſual Manner. The above mentioned Caſe of Colonel *Townſhend* ſeems inexplicable on any other Hypotheſis; but when this is once granted, it admits of a moſt eaſy Solution, it being no more difficult to conceive how, by repeated Endeavours, we ſhould get the better

better of that Neceſſity, whereby the Heart moves, according to the Laws the Mind has originally impoſed on itſelf, than it is to conceive how the Mind can get the better of that Neceſſity, whereby our Eyes are moved uniformly.

It is indeed no eaſy Matter to ſquint, after that the uniform Motions of our Eyes have once been eſtabliſhed by Habit and Cuſtom, yet we are taught by Experience, that the Thing is not altogether impoſſible; and ſeeing the Neceſſity whereby the *vital Motions* go on in a conſtant uniform Manner is of the ſame Kind with that Neceſſity whereby our Eyes continue their uniform Motion, if the Mind can get the better of the one, I ſee no Reaſon why it may not alſo ſometimes get the better of the other, and for a Time ſuppreſs all thoſe Motions on which Life depends: Nor is it more ſurpriſing that none of us are now able, by any Act of Volition, to retard, accelerate, or put a Stop to the vital Motions, than it is that we cannot now give our Eyes different Motions, nor move our Eyes up or down, without at the ſame time moving our Eye-lids.

§ 14. It is a common Obſervation, that the *Fœtus* in the Mother's Womb paſſes almoſt its whole Time in an unactive ſleepy State; and even Infants newly come into the World are

are ſeldom awake but when either Hunger calls for the Teat, or ſome Pain (the moſt importunate of all Senſations) or ſome other violent Impreſſion on the Body, forces the Mind to perceive and attend to it: And if we follow a Child from its Birth, and obſerve the Alterations that Time makes, we ſhall find that it comes to be more and more awake, thinks more and more of external Objects, and at laſt begins to know the Objects, which, being moſt familiar with it, have made laſting Impreſſions. If all this be duly conſidered, perhaps ſome Reaſon may be found for imagining, that in the Beginning of Life the Soul is wholly taken up in regulating and governing the internal Motions, which are yet difficult, by reaſon it has not been much accuſtomed to them; and therefore do require a cloſs and conſtant Application of Mind, which draws off its Attention from Things external, whence the Child muſt appear to be in an unactive ſleepy State: But as theſe Motions grow eaſier, the Mind by Degrees attends more and more to external Objects, ſeems leſs and leſs ſleepy and unactive, till by Uſe and Cuſtom theſe Motions do in Time become ſo eaſy as to be performed without our Knowledge or Attention, and that ſo neceſſarily as to make it impoſſible for us, by any Act of the Mind, to hinder them from going on in their uſual Man-

ner; and then the Mind being at full Liberty to employ all its Thoughts about other Matters, the Creature appears no longer ſleepy and unactive.

It were eaſy to illuſtrate and confirm this Doctrine by many familiar Examples; obſerve but Children when they firſt begin to walk, and you'll find, that the whole Mind is employed in conducting the Motions neceſſary for their Progreſſion, inſomuch that if any thing ſhall divide the Mind, and draw off its Attention, they preſently tumble down, by reaſon of the Difficulty that attends the Government of theſe Motions, which cannot be rightly conducted, while the Mind gives Attention to any thing elſe; but when Uſe and Cuſtom have once made theſe Motions eaſy and familiar, then they need but little Attention, and allow the Mind to employ its moſt ſerious and anxious Thoughts about other Matters. And what has been ſaid of Walking, is in like manner alſo true of Speaking, Singing, Playing on muſical Inſtruments, and many other Exerciſes, whoſe Difficulty is only overcome by Habit and Cuſtom.

Seeing then that there are many Actions that in the Beginning require ſo intire and undivided an Application of Mind, which nevertheleſs do in Time become ſo eaſy as to need but little Attention, I ſee not why it may not now, after all that has been ſaid on this Subject,

Subject, be allowed, that the Soul, in the Beginning of Life, is wholly taken up in the Government of the internal Motions, which by Uſe and Cuſtom do in Time become ſo eaſy as to be performed without our Knowledge or Attention, and that ſo neceſſarily as to make it impoſſible for us to hinder them from going on in their uſual Manner. But I am wearied of this Subject, upon which I ſhould not have dwelt ſo long, had it not been that I underſtood that ſome were greatly ſurprifed that I ſhould have ſuppoſed, in the *Medical Eſſays* of *Edinburgh* (*Vol.* iii. *p.* 258.) that *the Mind may poſſibly preſide over the vital and natural as well as the animal Motions:* To take off which Surprize, and to ſhow that the Thing is at leaſt poſſible, I have been obliged to enlarge beyond what I intended. Let us now proceed to the *final Cauſes* of this Change of Conformation in our Eyes.

§ 15. It has already been ſhewn, in general, that had the Eyes continued invariably the ſame, there could have been no diſtinct Viſion, but at one determined Diſtance, either great, middle or ſmall, according to the particular Diſpoſition of People's Eyes: But that the ſeveral *Phænomena*, ariſing from this Defect in our Eyes, and the Benefits we receive from the Change that happens in their Conformation, may be the better underſtood, it may not be

be improper that I ſhould here briefly explain the *Phænomena* that attend ſhort and long Sight, to which the Caſe before us is altogether ſimilar and analogous; this only excepted, that in the *Myopia* and *Viſus ſenilis* there is always ſome Latitude of Sight; whereas, did not the Cryſtalline change its Situation, diſtinct Viſion would be confined to one determined Diſtance, and with reſpect to Objects at a greater or leſſer Diſtance, the Eye would be myopical or preſbytical.

§ 16. By *Myopes*, or People that are ſhort-ſighted, I do not mean ſuch as have a ſmall *Pupil* or *turbid Humours*, who on that Account are alſo ſhort-ſighted, by reaſon that a ſufficient Quantity of Rays do not paſs to the *Retina*, unleſs when the Object is near; nor do I mean ſuch as have a Weakneſs of Sight, proceeding from a certain Degree of Calloſity, Paralyſis, or Inſenſibility in the *Retina*, by which the Viſion is very faint and obſcure, unleſs when the Object is very bright and luminous, or when, becauſe of its Proximity to the Eye, it ſends a greater Number of Rays to the *Retina*: But by *Myopes*, I underſtand, ſuch as have the *Cornea* and Cryſtalline, or either of them, too convex, or that have the Diſtance betwixt the *Retina* and Cryſtalline too great. From this Diſpoſition of the Eye it is plain, that

§ 17.

§ 17. 1*mo*, The diſtinct Picture of Objects at an ordinary Diſtance will fall before the *Retina*, and therefore the Picture muſt be confuſed on the *Retina* itſelf; from which Confuſion in the Picture, the Viſion will alſo be confuſed and indiſtinct. Whence,

2*do*, In order to ſee diſtinctly, they are obliged to bring the Object very nigh to their Eyes; by which means the Rays that are now more diverging are made to converge and meet at the *Retina*, where a diſtinct Picture will be made, from which the Object will be diſtinctly ſeen.

3*tio*, They that are ſhort-ſighted never look attentively to thoſe that ſpeak to them; for, by reaſon of this Defect in their Sight, they cannot exactly obſerve the Motion of the Eyes of thoſe that ſpeak, which contributes greatly to explain their Thoughts, and augment the Force of their Words; and therefore they are only attentive to their Diſcourſe, without fixing their Eyes on any Object. PLINY calls thoſe who have big and prominent Eyes *Hebetiores;* but it is not to be ſuppoſed that this Bigneſs in their Eyes can any way impair their Genius, or leſſen their Vivacity: But as thoſe who have ſuch Eyes are commonly ſhort-ſighted, they do not look attentively to thoſe that ſpeak to them; whence they may be thought to be more dull and ſtupid than

than others, for we commonly judge of People's Attention from the Diſpoſition of their Eyes.

4*to*, Short-ſighted Perſons need leſs Light for ſeeing clearly than others, and can eaſily read the ſmalleſt Print at the Light of the Moon, or in the Twilight, when ſuch as have good Eyes are not able to diſtinguiſh one Letter from another:

The Reaſon of this is plain; for when the Object is near, more Light enters the Pupil, and acts more powerfully upon the *Retina* than when it is at a greater Diſtance; but they who are ſhort-ſighted muſt, in order to ſee diſtinctly, bring the Object near to their Eyes: Whence the Impreſſions made on the *Retina* by the Rays of Light, and the Viſion that is cauſed thereby, will be ſtronger than in thoſe who cannot ſee diſtinctly but at a greater Diſtance. But beſides this, in the *Myopia*, the Pupil is very large, on which Account alſo more Light will enter the Eye, for rendering the Sight clear.

That the Pupil is large in myopical Eyes, is a common Obſervation; nor will the Reaſon thereof be difficult to any one who ſhall conſider that, 1*ſt*, The natural State of the Pupil is a State of Dilatation, as is manifeſt from its being very large, in Faintings, and upon firſt waking, as alſo after Death. 2*dly*, The Cauſe

Cauſe of the Contraction of the Pupil lies in the Mind, which wills the Contraction of its orbicular Fibres, either when the Light is too ſtrong, or when the Picture is not diſtinct upon the *Retina*. 3*dly*, When the Sight is perfect, that is, when it is neither too ſtrong or too weak, and more eſpecially when the Sight is weak, as in old Men, all Objects that are very near the Eyes will appear confuſed; on which Account, as well as on Account of the Quantity of Light that enters the Eye, the Pupil will be contracted: Whereas in ſhort-ſighted People, near Objects appear diſtinct, and therefore the Pupil does only contract, by reaſon of the too great Quantity of Light that enters the Eye, which alſo they can eaſily avoid, by retiring into a darker Place, as every body commonly does, when the Light is too ſtrong: And this is one Reaſon why the Pupil, which in Children is very large, does always continue ſo in thoſe who are ſhort-ſighted, and who are not obliged to contract it for ſeeing more diſtinctly. But in the *Viſus perfectus*, and eſpecially in the *Viſus ſenilis*, the Pupil muſt become ſmaller and ſmaller by Degrees; for by reaſon of its frequent Contraction for ſeeing near Objects more diſtinctly, the orbicular Fibres ſhrink, and become ſhorter; by which means the Pupil becomes narrower,

narrower, juſt as the Fingers of Work-people are much bended from the frequent Contractions of the *Flexores Digitorum*.

5*to*, *Myopes* have their Sight mended by a concave *Lens* of a due Degree of Concavity; for the Refraction being here too ſtrong in proportion to the Diſtance of the *Retina* from the Cryſtalline, this Refraction will be diminiſhed by the Interpoſition of ſuch a Glaſs and the diſtinct Image of the Object will be made to fall upon the *Retina*.

If CD (PLATE II. *Fig.* 2.) be a concave *Lens*, and B be the *Focus* of the Rays which flow from the Point A; that is, if the Rays which diverge form A, paſs through the Glaſs, and by the Refraction which they ſuffer in their Paſſage, proceed in ſuch a Manner as if they had diverged from B; and if the Diſtance at which a purblind Perſon ſees diſtinctly with his naked Eye be equal to the Diſtance of B from the Glaſs, ſuch a Perſon, will, by the Help of the Glaſs CD, be able to ſee the Point A diſtinctly; becauſe the Rays which flow from A, after they paſs through the Glaſs, fall upon his Eye with the ſame Degree of Divergence, as if they had iſſued from B, the Point of diſtinct Viſion. Hence it follows, that if in the Theorem laid down by Writers of Optics for finding the *Focus* of double

ble Concaves expoſed to diverging Rays, namely $F=\frac{RD}{R\times D}$, wherein F denotes the *Focus*, D the Diſtance of the Point of Divergence, and R the *Radius* of the Concavity; I ſay, if in this *Theorem* we ſuppoſe F to denote the Diſtance at which the purblind Perſon ſees diſtinctly without a Glaſs, and D the Diſtance at which he ſees diſtinctly by the Help of the Glaſs, by clearing R, we ſhall have $R=\frac{FD}{D-F}$; that is to ſay, the *Radius* of the Concavity of a double Concave of equal Concavities, which enables a purblind Perſon to ſee an Object diſtinctly, when placed beyond the Reach of his naked Eye, muſt be equal to a Rectangle, under the Diſtance at which he ſees diſtinctly with his naked Eye, and the Diſtance at which it is required he ſhould ſee diſtinctly by the Help of the Glaſs, divided by the Difference of thoſe Diſtances: For Inſtance, if a Perſon with his naked Eye can read at the Diſtance of three Inches only, and if it be required to find the *Radius* of ſuch a Glaſs as ſhall enable him to read at the uſual Diſtance of eighteen Inches: In this Caſe, F being equal to three Inches, and D to eighteen, their Product is fifty four; which being divided by their Difference, which is fifteen,

gives three and $\frac{3}{5}$ in the Quotient; which ſhews, that the *Radius* of the Glaſs muſt be three Inches and three 5ths nearly.

Where the Diſtance at which it is required the purblind Perſon ſhould ſee diſtinctly is infinite; or, in other Words, where it is ſo great as that the Diſtance to which the Power of his naked Eye reaches, bears no ſenſible proportion to it, there D—F becomes equal to D; and, of Courſe, R becomes equal to F; ſo that, in order to ſee ſuch Objects as are very remote, purblind Perſons muſt make Uſe of concave Glaſſes, whoſe *Radii* are equal to the Diſtances at which they ſee diſtinctly with their unarmed Eyes. But as all Concave-glaſſes repreſent Objects under a leſs Angle, they muſt appear leſs than to the naked Eye; which is what ſurpriſeth the moſt ſuch as are ſhort-ſighted, and who, for Want of Knowledge in Optics, are pre-poſſeſſed with the Opinion, that Objects are always beſt ſeen when they appear largeſt.

6*to*, Their Sight will alſo be mended by looking thro' a ſmall Hole ſuch as that made by a Pin in a Card:

For the little luminous Pencils, which have for their *Apex* a Point in the Object, and for their *Baſis* the little Hole, will, by Reaſon of their Acuteneſs proceeding from the Smallneſs of the Hole, take up ſo ſmall a Space on the *Retina*,

*Retina*, as to occaſion but little Confuſion in the Picture; whereas, without the Interpoſition of the perforated Card, the luminous Pencils will have a Baſe as large as the Pupil itſelf; and conſequently muſt occupy a much larger Space upon the *Retina*, from which the Picture, and the Viſion thereby occaſioned, will be a great deal more confuſed than when the Object is viewed thro' the ſmall Hole. And this is the Reaſon why ſhort-ſighted People, to ſee diſtant Objects more diſtinctly, call to Aſſiſtance their Eye-lids, which they ſhut ſo as to leave open only a very ſmall Slit, by which the Confuſion in the Picture is in ſome Meaſure corrected, and the Sight is made more diſtinct tho' leſs clear. And it is from this cloſing of their Eye-lids, that ſhort-ſighted Perſons were antiently called *Myopes*.

7*mo*, Short-ſighted Perſons commonly become leſs ſo, as they advance in Years, and that becauſe the Humours of the Eye do daily waſte and decay; from which Decay in the Humours, the *Cornea* ſhrinks, and becomes leſs convex, and the Cryſtalline becomes flatter than before, by which means the Rays of Light will be leſs refracted, and will not meet ſo ſoon behind the Cryſtalline; and therefore the Image on the *Retina*, and the Viſion cauſed thereby, will be more perfect and diſtinct, and the Eye will be enabled to ſee

at

at a greater Diſtance, than when the Refraction was ſtronger in the more plump and convex Eyes:

Whence we may ſee, why very young Children never take notice of any Thing but what is cloſs upon their Eyes; for in them the *Cornea* is too convex and prominent to allow them to ſee diſtinctly, or attend to Objects at an ordinary Diſtance. This has been taken notice of by DES CARTES; and ſkilful Painters ſeem to be well acquainted with it, who therefore, when they paint young Children in *Profile*, give the *Cornea* an uncommon Convexity.

Some very great Opticians have queſtioned, whether Short-ſightedneſs grows leſs by Age, and ſeem to think this rather an Hypotheſis than Matter of Fact. (See SMITH's *Optic. Remarks*, *Art.* 61.)

This, I imagine, they have been led into from their having obſerved, that ſhort-ſighted People have continued to read at a very ſmall Diſtance, even in old Age: But as thoſe whoſe Sight is perfect, come to read at a greater Diſtance when old, becauſe of the Flatneſs of their Eyes, which always increaſes as they advance in Years; there can be no doubt, but the Eyes of ſhort-ſighted Perſons muſt alſo become flatter, the older they grow;

and

and being flatter, they muſt ſee at a greater Diſtance.

Nor is it any ſolid Objection to this, that they continue ſtill to read at a ſmall Diſtance; for the cauſe of Short-ſightedneſs is not a Want of Power to vary the Conformation of the Eye, but that the Quantity of Refractions is always too great for the Diſtance of the *Retina* from the *Cornea*; and therefore, if ſhort-ſighted Perſons can read a ſmall Print diſtinctly at two different Diſtances, whereof the larger is double the leſſer, which I believe moſt of them can do, ſuppoſe, at the Diſtance of 2 Inches and 4 Inches; this ſhort-ſighted Perſon will chuſe to read at the greater Diſtance 4 Inches, becauſe at any leſſer Diſtance it is not ſo eaſy to keep the Head from ſhading and darkening the Print; and beſides, when the Book is near the Eyes, the Eyes are more fatigued, becauſe of the greater Motion that is required to run over a Word, and, becauſe of the ſtronger Effort that muſt be exerted by the adducent Muſcles, to keep the Eyes fixed on ſo near an Object; this Perſon will therefore hold the Book at the fartheſt Limits of diſtinct Viſion, which we have ſuppoſed to be 4 Inches. But, when by Age his Eyes grow flatter, ſo as to ſee diſtinctly at the Diſtance of 3 Inches and 6 Inches, he will not then hold the Book at

the

the fartheſt Limits of diſtinct Viſion, *viz.* 6 Inches, but will ſtill continue to read at about his uſual Diſtance 4 Inches; for tho' he can read diſtinctly at the Diſtance of 6 Inches, yet as now the Pupil is ſmaller, and the Humours of the Eye are leſs tranſparent than before, more Light will be required for making the Object appear ſufficiently clear and bright; and therefore he will ſtill continue to read at about 4 Inches Diſtance, that the Eye may receive more Light for making a ſufficient Impreſſion on the *Retina*: And even tho' he needed not more Light, his having been accuſtomed to read at 4 Inches Diſtance, would influence him to continue to read at that Diſtance, unleſs he found ſome Inconveniency in ſo doing; which is far from being the Caſe.

8*vo*, Small lucid Bodies, when at a conſiderable Diſtance, appear Great, Round, and frequently full of Spots.

For underſtanding this, let H (PLATE I. *Fig.* 3.) be the Eye, and let the Candle A be the Object, which is here ſuppoſed to be at the Diſtance of about 60 Feet, and which, by reaſon of its Diſtance, may be conceived as a Point. The Rays of Light AB, AC, *&c.* will, after Refraction, in this *myopical* Eye, converge and meet it at a Point before the *Retina* as at *o*, and after that they will diverge and

and form on the *Retina* the large Image *de*, which will have the ſame Figure with the Pupil, and conſequently will be round.

From the extreme Points of this Image *d* and *e*, draw, thro' the Centre of the Eye L, the right Lines *d*LD, *e*LE; theſe Lines will be perpendicular to the *Retina*, at the Points *d* and *e*; and conſequently the Object A will, by means of its luxuriant Picture on the *Retina de*, be ſeen under the Angle DLE. If therefore about the Centre A, with the *Radius* AD or AE, the Circle ADE be deſcribed, the ſmall Object A will be ſeen uniformly extended over all that Circle, and conſequently muſt appear big and round.

Whence they that are ſkilled in Optics will eaſily ſee, that, 1*ſt*, When the ſmall Object A is at a very great Diſtance, the Appearance will alſo be very great. At ſixty Feet Diſtance, a Candle commonly appears a luminous Circle of about a Foot Diameter; but this will be greater or ſmaller, according to the Degree of Shortneſs of Sight, and Magnitude of the Pupil.

2*dly*, The nearer the Object is, the Appearance will be the leſs, and will approach the nearer to the natural Figure of the Object.

3*dly*,

3*dly*, When two or more Candles of unequal Magnitude are ſeen at a great Diſtance, they will appear equal, and if they are not far from one another, their circular Appearances will cut each other; thus a Luſtre full of Candles puts on the Appearance of a Globe of Fire.

4*thly*, If the Hand be gently brought before the Eye, before that any one of theſe circular Appearances are hid, ſome Part of each Circle will be made to diſappear; and this Part that is made to diſappear will lie on the ſame Side with the interpoſed Hand; whereas, in the *Viſus ſenilis*, it lies on the oppoſite Side, as will be ſhown below.

5*thly*, From this alſo it is eaſy to underſtand, why to all of us the Stars appear larger than they ought; for the Eye with reſpect to them being purblind, they are ſeen under a greater Angle, and conſequently muſt appear greater, for the ſame Reaſon that a diſtant Candle appears ſo to a *Myops*: Whence it is, that when the fixed Stars are viewed thro' a ſmall Hole made in a Card, they ſeem much leſs than when ſeen with the naked Eye; for the Luxuriancy of the Image being in ſome meaſure corrected by the Smallneſs of the Hole in the Card, the Stars themſelves muſt neceſſarily appear ſmaller: And this alſo is one Reaſon why the Teleſcope, which increaſes the

the Magnitude of all other Objects, diminiſhes that of the Stars; for this optical Inſtrument does not here magnify ſo much by increaſing the Angle under which they are ſeen, as it diminiſhes by uniting the Rays at the *Retina*, and by that means correcting the Luxuriancy of the Picture: Nor is it any ſolid Objection to this, That the Sun and Moon, with reſpect to the Diſtance of both which, no doubt, the Eye is alſo myopical, do appear larger when ſeen with a Teleſcope than with the naked Eye; for it muſt be obſerved, that at a given Diſtance, the Luxuriancy in the Image, proceeding from the Rays not being accurately united at the *Retina*, is always the ſame, and is not augmented according to the Magnitude of the Object; and therefore, in large Bodies, ſuch as the Sun and Moon, it bears but a very ſmall Proportion to the true Magnitude of the Image; and conſequently, when this Luxuriancy is cut off by the Teleſcope, it makes no ſenſible Detraction from the Magnitude that ariſes from the Augmentation of the viſual Angle. And of the ſame Kind with this Appearance of the Stars is alſo the Appearance of a diſtant Candle, which in the Night-time ſeems larger than it ought to moſt Eyes; becauſe the Eye, with reſpect to its Diſtance, is ſomewhat purblind, and the Pupil being then much dilated, muſt greatly increaſe the Luxuriancy

riancy of the Picture: But if this ſame Candle be viewed in Day-light, or even if it be viewed by Night from a well lighted Room, or if a Flaſh of Lightning ſhould happen at the Time it is viewed, it will not appear much bigger than it ought, by reaſon of the Contraction of the Pupil, which corrects the Luxuriancy of its Picture on the *Retina*.

As to what concerns the Spots that are ſo frequently obſerved by myopical Eyes; theſe may proceed from ſome little Extravaſations, various Swellings, or other Defects in the *Retina*, which, by intercepting the Rays, will occaſion a Defect in the Picture, and by conſequence, a ſimilar and correſponding Defect or Spot in the Object.

Theſe Spots commonly vaniſh, or at leaſt become leſs ſenſible, when the Object is brought nearer the Eye, and within the Limits of diſtinct Viſion; for the Rays, which are now exactly united upon the *Retina*, by being more crowded, have their Force augmented; by which means, a ſenſible Impreſſion is made upon the *Retina* thro' theſe Extravaſations, which are too thin to intercept wholly theſe Impreſſions, unleſs when they are weak and faint: And this is the Reaſon why theſe Spots are always moſt ſenſible to thoſe who have a ſmall Pupil, and eſpecially to thoſe who are ſhort or long-ſighted: From which

alſo

alſo we may ſee, why, in a preſbytical Eye, the Spots, which were formerly very ſenſible, become ſo faint, when the Object is viewed thro' a convex Glaſs of a due Degree of Convexity; for by means of this Glaſs more Rays are made to enter the Eye, which being united exactly at its Bottom, muſt ſtrike the *Retina* ſtrongly enough for to make a ſenſible Impreſſion thro' theſe Extravaſations, which will render the Spots ſo faint and obſcure, as to be ſcarce any more obſervable. And what has been ſaid with reſpect to theſe Spots, when occaſioned by ſmall Extravaſations, or other Defects in the *Retina* that intercept the Rays, will alſo hold, when they are occaſioned by a Calloſity, or any Degree of Paralyſis or Inſenſibility in ſome Parts of the *Retina*, by which the Impulſe or Stroke received from the Rays is made leſs ſenſible.

But, beſides theſe Defects in the *Retina*, there is yet another Cauſe which may give occaſion to thoſe Spots both in the *Myopia* and *Viſus ſenilis*, and that is certain ſmall opaque Marks on the *Cornea* itſelf, or any where within the Eye, which, by intercepting ſome of the Rays, muſt occaſion a Defect in the Picture, from which Defect a kind of dark Spot will be ſeen in the Object.

Thus in the Eye of a *Myops*, (See ſtill PLATE I. *Fig.* 3.) if there is any Opacity in the

the *Cornea*, or within the Eye, which intercepts the Rays *Bbe*, *Ccd*, and VL*a*, there will be a Defect in the Picture at *e*, *d* and *a*, from which alſo the external Appearance will be deficient at the correſponding Points E, D and A, where, by conſequence, dark Spots will be ſeen: For it is hear to be obſerved, that there is not one Point in the Picture that is formed by a Plurality of Rays which conveen at that Point, but every Ray goes to a different Point of the Picture, both in the myopical and preſbytical Eyes; and therefore, when any of of the Rays are intercepted, that Part of the Picture to which ſuch Rays belong, will not be illuminated, which muſt occaſion a correſponding Defect in the Appearance of the Object; but in the *Viſus perfectus*, where the Rays that come from the ſeveral Points of the Object are ſo refracted as to meet again at ſo many correſponding Points in the *Retina*, every Point of the Picture is formed by a Cone or Pencil of Rays, whoſe Baſis is the Pupil; and therefore tho' ſome of thoſe Rays be intercepted, yet no Part of the Picture will be darkened, and conſequently no Defect will be ſeen in the Object from any ſuch Opacity in the *Cornea* or Humours of the Eye, unleſs this Opacity be in the Back-part of the vitreous Humour, where the Pencil is narrow, and intercepts the whole Pencil.

If

If any deſire an experimental Proof of this, let them repair to a *Camera Obſcura*; and having made ſome dark Spots in the *Lens*, by applying Patches, or any ſuch like ſmall opaque Bodies, let this Glaſs be placed at a round Hole made in the Window-ſhut of the dark Chamber for refracting the Light which comes from an Object without Doors, ſo as its Picture may be painted on a Sheet of white Paper, placed behind the *Lens*; if this Paper be at a due focal Diſtance from the *Lens*, no Defect or Spot will be found in the Picture; but if the Diſtance of the Paper be greater or ſmaller, than that at which the Rays conveen, for making the Picture diſtinct, as many dark Marks will be ſeen in the Picture as there are Spots in the Glaſs: And it is only from this Principle that any ſatisfactory Account can be given how it comes to paſs, that when a ſmall opaque Body, that is, a Body that is leſs than the Pupil, is held cloſs to the Eye, before which ſeveral Candles are placed at a great Diſtance, ſuppoſe 60 Feet, if the Eye attend to this ſmall Object, or, which is the ſame thing, if it endeavours to accommodate itſelf to its Diſtance, this Object will be ſeen multiplied according to the Number of Candles, and will appear like a dark Spot in each of the Candles.

This

This *Phænomenon* ſeems very extraordinary to ſuch as have no Knowledge in Optics; but from the Principles already eſtabliſhed, it admits of a moſt eaſy Solution. For when the Eyes endeavours to ſee the ſmall Object, it becomes myopical with reſpect to the Candles; and therefore on each of their Pictures on the *Retina* the dark Shade of the interpoſed Body will be caſt; from which a correſponding dark Spot muſt be ſeen in each of the Candles: But when the Eye does not attend to this ſmall Body, but it is well diſpoſed for ſeeing the Candles diſtinctly, this interpoſed Body will not be multiplied, nor will any dark Mark be ſeen in any of the Candles, becauſe every Point of their Picture is now compoſed of a Cone or Pencil of Rays, which, after Refraction, are made to conveen at that Point; and therefore, tho' ſome of the Rays belonging to each Pencil are intercepted, yet every Point of the Picture will be ſufficiently, and indeed equally illuminated by the Rays that are not intercepted; and conſequently no Defect or Obſcurity will be ſeen in any Part of the Candles, and the ſmall opaque Body will itſelf ſeem perfectly diaphanous.

9*no*, Another *Phænomenon* belonging to *Myopes* is, that they read and write very ſmall Characters, by reaſon that the viſual Angle is enlarged by the Proximity of the Object:

Whence

Whence alſo it is, that great Characters fatigue their Eyes, becauſe of the Motion that is required to run over a Word.

10*mo*, In reading, they generally hold the Book towards the Side of their Head, that it may be ſufficiently illuminated and not darkened by the Shade of their Head.

11*mo*, No Object being diſtinctly ſeen but what is very nigh, in order to ſee it with both Eyes, their *Axes* muſt be very converging; which Situation of their Eyes being painful and laborious, becauſe of the ſtrong Effort that muſt be exerted by the adducent Muſcles, they are oftentimes obliged to turn away one of their Eyes; whence proceeds a double Viſion, which in reading does frequently oblige them to ſhut one of their Eyes, that they may avoid the Confuſion that is occaſioned thereby.

12*mo*, There is yet another *Phænomenon* which happens to all Kinds of Sights, but is commonly a great deal more ſenſible to thoſe that are purblind than to others, becauſe that in them the *Cornea* is more convex and elevated, *viz.* They ſee an Object that they do not look at, and they do not ſee this ſame Object when their Eyes are turned towards it.

This ſeems a Paradox in Optics, but it is agreeable to Experience; for having applied

to

to the Side of the Head any thin black Body, ſuch as the Brim of a Hat, ſo as it may abſcond the Objects that are upon that Side; without moving the Eye, turn the Head with the black Body that is fixed to its Side, till you ſhall perceive a certain ſmall white Object placed upon a black or brown Ground; then keeping the Head fixed in this Situation, let the Eye be directed to the Object, and it will vaniſh.

This Experiment is apt to ſurpriſe at firſt; but it is very eaſy to account for it from the Conformation of the Eye: For If AIK (PLATE I. *Fig.* 4.) be the Eye, BL the black Body placed near to the Eye, and if O be the white Object; the Pupil *fc* being turned towards M, the Rays which come from the Object O, in paſſing by the black Body BL, will fall obliquely upon the *Cornea* at A, and will be refracted by the aqueous Humour, ſo as to paſs through the Pupil *fc*, and conſequently will fall upon ſome Part of the *Retina*; by which means the Object O will be ſeen, tho' the Eye is not directed to it: But if, without moving the Head, the Eye be turned towards O, it muſt move nearly upon its Centre H, from which the *Cornea* and Pupil will get the Poſition given them in the Figure; and therefore, tho' even in this Poſition of the Eye, the Rays that come from O,

and

and that paſs over the Extremity of the Obſtacle at B, ſhould be ſuppoſed to fall upon the *Cornea*, yet by reaſon of the Obliquity of their Incidence, they can never be ſo refracted as to enter the Pupil ED, but muſt be loſt upon the *Uvea;* from whence it is evident, that the Object O will not be ſeen when the Eye is directed to it.

§ 18. I have done with the Short-ſight, and ſhall now ſhortly explain the *Phænomena* that belong to the weak or preſbytical Sight.

*Preſbytæ*, or weak-ſighted People, are ſuch as have the *Cornea* and Cryſtalline, or either of them, too flat, in proportion to the Diſtance betwixt the Cryſtalline and *Retina:* From which Fault in the Conformation of their Eyes, it clearly follows, that,

1*mo*, The Rays of Light that come from the ſeveral Points of an Object at an ordinary Diſtance, will not be ſufficiently refracted, and for want of ſufficient Refraction will not meet at the *Retina*, but beyond it; and therefore the Picture on the *Retina*, and the Viſion cauſed thereby, will be imperfect and indiſtinct, more or leſs, as the Object is nearer or farther off. Whence,

2*do*, In order to read, they muſt remove the Book to the Diſtance of two or three Feet;

whereas in their Youth they uſed to read at one Foot Diſtance. But,

3*tio*, As the Picture on the *Retina*, and the viſual Angle under which the Object is ſeen, are then leſſened, and that in proportion as the Diſtance of the Object is increaſed; it is evident, that ſmall Objects will not be ſeen well, even when their Diſtance is ſuch as is neceſſary for making their Picture on the *Retina* diſtinct. Whence it is, that ſometimes they cannot read at all, eſpecially if the Characters be ſmall, without the Aſſiſtance of Spectacles; which are ſtill the more neceſſary, becauſe that when the Object is at a Diſtance, leſs Light enters the Eye, and conſequently the Picture, and the Impreſſion made on the *Retina* thereby will be fainter.

But for a fuller Explication of this Point, and to ſhow how ſmall Objects may become inviſible to the naked Eye, even when their Picture is diſtinct upon the *Retina*, it muſt be obſerved that there is a *Minimum Viſibile*, and that all Objects, however ſmall, if at all ſeen, are ſeen of that Bigneſs. For the *Retina* being compoſed of ſmall Fibres, not unlike a Piece of Pluſh, with the Ends of the Threads turned towards the Cryſtalline, all the other ends of them being terminated in the Brain, there can be no more diſtinct Senſations than there are diſtinct Threads to convey the Impreſſion on them,

them, and the Eye will be incapable of diſtinguiſhing the Parts of any Picture that is no bigger than one of theſe Figures compoſing the *Retina;* ſo that if any Object be ſo far removed from the Eye, as to make the Picture of it on the *Retina* leſs than one ſingle Fibre, that Object becomes inviſible, if it be but of a dull Radiation, becauſe of the Weakneſs of the Impreſſion made on the Fibre; but if it be of a very bright and powerful Radiation, the whole Filament is moved, by having one Part of it powerfully acted on; and therefore the Senſation is the ſame as if the Object were much bigger, and did take up or cover the whole End of the Filament: And this to me ſeems to be the Reaſon why the Stars appear all of the ſame Bigneſs, and why even to the naked Eye they appear many thouſand times bigger than they really are, and even as big as through a long Teleſcope, which would not be, if our Sight were ſufficiently fine and nice.

I have ſaid, that when an Object is ſo far removed from the Eye, as to make the Picture of it on the *Retina* leſs than one ſingle Fibre, that Object becomes inviſible, if it be of a dull Radiation, by reaſon of the Weakneſs of the Impreſſion: For the Strength of the Impreſſion, when the Picture covers the whole End of the Fibre, will be to its Strength, when

when it only covers a Part of it, as the Magnitude of the whole Fibre is to the Magnitude of that Part of it that is taken up by the Picture.

But there is yet another Reaſon, why an Object is not ſeen, when its Picture is leſs than one ſingle Fibre, and that is, that this ſame Fibre does not only receive an Impreſſion from this Object, but it does alſo receive an Impreſſion from the extreme Parts of the contiguous Objects by which it is terminated; which, if they be of a bright Radiation, muſt prevail over the other Impreſſion, and, by their Prevalence, render the Object itſelf inviſible:

Thus, if one of the Fibres compoſing the *Retina* be ſuppoſed as big as *ao* (*Fig.* 5. PLATE I.) the ſmall Object IE will, on the *Retina*, make a Picture betwixt *i* and *e*, and the contiguous Objects OI and AE will on the ſame Fibre *ao*, form a Picture at *oi*, and *ae*, which being white, will act more powerfully on the Fibre *ao*, than does the Picture of the ſmall black Object IE; and conſequently this ſame Object IE muſt become inviſible, and the more bright and luminous Bodies OI and AE muſt appear extended over all the Space OIEA.

The learned Dr. HOOK, by an eaſy Experiment, found the *Minimum Viſibile* in moſt Eyes to be comprehended within an Angle

Angle of one Minute, (See *his poſthumous Works, p.* 12. *and* 97. Whence it is, that whatever is ſeen, is ſeen of that Bigneſs, or under that Angle: Thus every Star that the Eye diſcovers appears to be of the Bigneſs of a Minute at leaſt, and ſo it is conceived really to be; tho' yet when we come to examine its Diameter by the Help of a Teleſcope we really find it to be but ſome few Seconds, or 60th Parts of ſuch an Angle: and this alſo is the Reaſon why, if there be two, three, or an hundered ſmall Stars ſo near together, as that they are all compriſed within the Angle of one Minute, the Eye has a Senſation of them all as if they were one Star, and diſtinguiſhes them not one from another; becauſe all their Pictures, falling upon the ſame nervous Fibre, make but one Impreſſion on the *Senſorium*; which being ſtrong and powerful, prevails over, and deſtroys the more faint and languid Impreſſions made by the Picture of the Interval that is betwixt them: And the Caſe is exactly the ſame when an old Man removes the Book to a very great Diſtance from his Eyes; for if the black Lines forming the Letters are ſeen under a leſs Angle than a Minute, they will be wholly obliterated by the more powerful Impreſſions of the White Paper that terminates them.

And

And here, by the way, it may not be improper to obſerve, that this Experiment of Dr. HOOK ſerving to determine the *Minimum Viſibile*, affords us a pretty certain Proof of the Magnitude of our nervous Fibres: For if *ao* (See ſtill *Fig.* 5. PLATE I.) be the End of one ſingle Fibre, the ſmall Object IE, which is here ſuppoſed to be bright and luminous, will, by Means of its Picture on the *Retina ie*, move the whole Fibre, and the Appearance of the Object will be the ſame as if its Picture were extended over the whole End of the Fibre *ao*; and therefore, if from the extreme Points of the Fibre *a* and *o*, the right Lines *ax*A, *ox*O are drawn thro' the Centre of the Eye *x*, theſe Lines will be perpendicular to the *Retina* at the Points *a* and *o*, and conſequently the ſmall Object IE will be ſeen under the Angle O*x*A; which Angle being given, the Angle *oxa*, which is equal to it (both being Angles at the Vertex *x*) will alſo be known, from which the Diameter of the nervous Fibre *ao* may eaſily be found.

Thus, if the Angle O*x*A be one Minute, as Dr. HOOK found it in moſt Eyes, tho' there was ſome that could ſee to the third of a Minute, the Angle *oxa* will alſo be one Minute, which is the 60th Part of a Degree, or the 21,600 Part of a Circle: Whence if the Eye be ſuppoſed to be one Inch Diameter, or three

three Inches in Circumference, the Diameter of the nervous Fibre *ao* will be the 21,600 Part of three Inches, or the 7200 Part of one Inch, which is the 600 Part of a Line; and if ten Hair-breadths make a Line, which is pretty near the Truth, its Diameter will not exceed the 60 Part of the Diameter of a Hair: Whence the nervous Fibres themſelves will be no bigger than the 3,600 Part of an ordinary Hair. And if it be ſuppoſed that one can ſee under an Angle that is no bigger than the third of a Minute, as Dr. Hook found that ſome could do, then the Bigneſs of the nervous Fibres compoſing the *Retina* will not exceed the 32,400 Part of an ordinary Hair, which is a ſurprizing and almoſt inconceivable Smallneſs; and the more ſo, becauſe each of theſe Fibres are ſuppoſed hollow Canals or Tubes in which the Spirits flow. How fine and ſubtile muſt then the Spirits themſelves be?

But this is not all; for if Birds can ſee diſtant Objects as well as Man, which ſeems very probable, becauſe of the Facility which they have in returning to Places at a great Diſtance from which they had gone, and eſpecially becauſe Birds of Prey are obſerved to perceive very ſmall Animals at a great Diſtance; I ſay, ſuppoſing that Birds ſee Objects at a Diſtance as well as we do, it is neceſſary that the Fibres which compoſe their optic Nerves

Nerves and *Retinæ* be much more fine and delicate than in Men: For, since their Eyes are smaller than ours, the Image of Objects on the *Retina* will also be smaller:

Whence it is manifest, that a similar Conformation of the Humours is not alone sufficient to make an equal Perfection in the Sight: For Instance, an Eye of two Lines Diameter, (than which there are many smaller) which has the Humours of a similar or like Figure to those of a Human Eye, whose Diameter is an Inch, can never see Objects at a great Distance as distinctly as we do, unless the Organ of Sight, on which the Pictures of Objects are received, be 36 times finer and more sensible than it is in our Eyes: For the Picture of the Object will be 36 times smaller in their small Eye than in ours, the Surfaces of the Globes of their Eyes being to one another as 1 is to 36. And therefore, if the nervous Fibres of our *Retina* do not exceed the 32,400 Part of a Hair; in Animals, whose Eyes are only two Lines in Diameter, they will be no bigger than the 1,166,400 Part of an ordinary Hair, which is truly a prodigiously surprising and almost incredible Smallness; and yet upon Calculation, it is as certain as any Proposition in EUCLID, that they can be no bigger, if we allow them to see Objects at a Distance

ſtance as diſtinctly as Men do. But I muſt go forward.

4*to*, They who are long-ſighted require more Light than others for enabling them to read; for being obliged to remove the Book to a conſiderable Diſtance, that the Rays which come from the ſeveral Points of the Object may meet again in ſo many correſpondent Points on the *Retina*, without which there can be no diſtinct Viſion, leſs Light will enter the Eye, and the Impreſſion made thereby on the *Retina* will be too faint, unleſs the Object be more ſtrongly illuminated, than what is neceſſary either in the ſhort or perfect Sight; in both which, the Proximity of the Object does in ſome Meaſure recompenſe its Obſcurity. Add to this, that in the preſbytical Eye the Pupil is always ſmaller, on which Account alſo more Light will be required for making a ſufficient Impreſſion on the *Retina*. And this is the Reaſon why,

5*to*, The preſbytical Eye receives greater Benefit from the Uſe of a convex *Lens*, than the Eye of a *Myops* does from one that is concave: For the Property of ſuch Glaſſes being to collect the Rays, more of them will be made to enter the Pupil; and as in ſuch Eyes the Refraction is too weak, the Rays which flow from a Point at an ordinary Diſtance, and which, for want of ſufficient Refraction, do

not concur at the *Retina*, but at ſome Place beyond it, will, by means of this Glaſs, be made to meet at the *Retina*: Whence they that are long-ſighted muſt receive a double Advantage from convex Glaſſes; for by them the Picture is not only diſtinct upon the *Retina*, but is alſo as ſtrong and lively as if the Pupil had been much larger.

To determine the proper Convexity of Spectacles for the Uſe of old Men; Let CD (PLATE I. *Fig.* 6.) be a convex *Lens* or Spectacle-Glaſs, A the *Focus* of the Rays which diverge from B, that is to ſay, the Rays which diverge from B and paſs thro' the *Lens*, do afterwards proceed in ſuch a Manner as if they had diverged from A, and let the Diſtance at which an old Man can ſee diſtinctly with his naked Eye, be equal to the Diſtance of A from the Glaſs; this Man will be able, by the Aſſiſtance of the Glaſs, to ſee the nearer Point B diſtinctly; becauſe the Rays which iſſue from that Point in paſſing thro' the Glaſs acquire the ſame Degree of Divergence with thoſe which flow from A the Point of diſtinct Viſion, and of conſequence may as eaſily be brought together on the *Retina* by the refractive Power of the Eye; hence if we take the *Theorem* demonſtrated by the Writers of *Dioptrics* for finding the *Foci* of double Convexes of equal Convexities, and fit it to the Caſe before

before us, where the *Focus* is imaginary, we ſhall have $F = \frac{RD}{R-D}$, in which F expreſſes the *Focus*, D the Diſtance of the Point of Divergence, R the *Radius* of the Convexity; if then we ſuppoſe F to denote the Diſtance at which an old Eye ſees diſtinctly, and D the nearer Diſtance at which it is required to make it ſee diſtinctly with the Aſſiſtance of a Glaſs, by clearing R, we ſhall find it equal to $\frac{FD}{F-D}$; ſo that the *Radius* of ſuch a double Convex of equal Convexities as enables an old Man to ſee nigh Objects diſtinctly, muſt be equal to a Rectangle under the Diſtance at which he ſees diſtinctly with his naked Eye, and the Diſtance at which he is to ſee, by the Help of the Glaſs, divided by the Difference of thoſe Diſtances.

To illuſtrate this by an Example; ſuppoſe an old Man cannot with his naked Eye read at a leſs Diſtance than four Feet, and it is required to aſſign the *Radius* of Spectacles which ſhall enable him to read at the Diſtance of a Foot and a Half; in this Caſe F is 4 Feet and D is $1\frac{1}{2}$ Foot, and their Product is ſix, which, when divided by their Difference, to wit, two and an Half, gives $2\frac{4}{10}$ in the Quotient; which ſhews that the Spectacles muſt be ground to a *Radius* of two Feet and four tenths.

If

If F be infinite, which is the Case where the Eye can see nothing but what is extremely remote, then F—D is equal to F, and of Consequence R is equal to D; so that, where an old Man can see no Objects distinctly but such as are very far off, in order to see distinctly at nearer Distances, he must for each Distance use such Spectacle-glasses as have their *Radii* equal to the Distance.

If D be given, then R becomes equal to $\frac{F}{F-i}$; and, forasmuch as the Proportion of F to F—i increases as F lessens, R must do so too; which shews that where the Distances at which two old Eyes, when unarmed, can see distinctly, are different; in order to make them see distinctly at any lesser given Distance, the Eye which can see at the smaller Distance, must be furnished with a Glass of a greater *Radius* than the other. And herein lies the whole Secret of younger and older Spectacles, those being deemed the youngest which are ground to the largest *Radius*, and which of Consequence are the less convex. But I must proceed.

*6to*, Long-sighted People see more distinctly through a small Hole, such as that made by a Pin in a Card: For by this Hole the Picture will be rendered more distinct upon the *Retina*, and

and that for the ſame Reaſon that has been given, why in a *Myops* the Sight is mended, by looking through a ſmall Hole: But as part of the Light is intercepted by the Card, and as long-ſighted People require more Light than others for rendering their Sight equally clear, they will not reap ſo much Advantage from the Interpoſition of the perforated Card as thoſe who are ſhort-ſighted, and who, by reaſon of the Proximity of the Object, can eaſily read in the Twilight, when ſuch as have not that Defect in their Eyes cannot diſtinguiſh one Letter from another.

*7mo*, They who are long-ſighted commonly become more ſo as they advance in Years; for the *Cornea* and Cryſtalline become flatter and flatter continually, becauſe of the daily Waſte and Decay that happens in the Humours of the Eye; whence at laſt they cannot ſee at all without the Aſſiſtance of Spectacles, which ſupply the Refraction that is wanting in the Eye, by rendering the Rays converging, which can never be done by the alone Poſition of the Object from which they proceed: For if it is near, they enter the Eye diverging; and if it is far off, they enter nearly parallel.

But, tho' the preſbytical Eye does commonly become more and more ſo by Degrees; yet ſome have been found who at laſt recover their Sight

Sight again, and have no further Occaſion for their Glaſſes to enable them to read. There are many Cauſes which may produce this Effect, but to me it ſeems probable that it ſhould chiefly ariſe from a Decay of the Fat in the Bottom of the Orbit; whence the Eye, for want of the uſual Preſſure at its Fund, is, by the Preſſure of the Muſcles and Fat towards the Sides of the Eye, reduced to an oblong Figure, by which the *Retina* is removed to a due focal Diſtance from the Cryſtalline.

From this it is eaſy to ſee, how, from a contrary Cauſe, the Sight, which was perfect till about the 20th or 25th Year of their Age, does in ſome for a certain Time become more and more myopical by Degrees: For if at this Time the Muſcles of the Eye become bigger and more fleſhy than before, or if the Fat ſhould be collected in greater Plenty towards the Side of the Eye, the Eye will, by Reaſon of the Preſſure on its Sides, be reduced to an oblong Figure, and the *Retina* will be puſhed back to too great a Diſtance from the Cryſtalline, which obliges them to bring the Object they would ſee diſtinctly nearer to their Eyes, that its Picture may be diſtinct upon the *Retina*; whereas, before that, they uſed to read at an ordinary Diſtance.

8*vo*,

8*vo*, In the preſbytical or weak Sight, as well as in that which is perfect, the Eye is more ſenſibly affected, and ſuffers more by great Light than when the Sight is myopical, with the ſame opening of the Pupil; for the luminous Bodies that ſurround us, and which are not very near us, ſend Rays into the Eye, which in the *Viſus perfectus* are brought together, and united upon the *Retina*, and make but a very ſmall Baſe in the preſbytical Eye; whence the Impreſſion made on the *Retina* will be ſtrong and lively in both theſe Eyes, and muſt therein cauſe ſome Pain or Uneaſineſs, which does not happen in the myopical Sight, becauſe theſe ſame Rays make a larger Baſe on the *Retina*; for all things being equal, the myopical Eye always ſees Objects more confuſedly than does either the perfect or preſbytical Eye, and this Confuſion is cauſed by the Space which the Rays that come from each Point of the Object occupy on the Fund of the Eye. And this by the by is another Reaſon why the Pupil, which in Children is very large, continues more ſo in thoſe who are ſhort-ſighted than in thoſe whoſe Sight is either perfect or weak, and who, by Reaſon of the too ſtrong Impreſſion made upon the *Retina*, by bright and luminous Objects, are obliged to contract the Pupil, for keeping out a Part of the Light.

9*no*,

9*no*, To a presbytical Eye, small lucid Objects, such as a lighted Candle, or a small Hole of a Line or two Diameter, which is luminous, because of the Light which passes it, appear big and round; and if the Rays on either Side of the Pupil be intercepted by the Interposition of any opaque Body, the opposite Side of the Appearance will be hid, and the opaque Body itself will appear as if it were on the contrary Side to that where it really is.

This *Phænomenon* will, no doubt, seem very extraordinary to some; for since we always judge that Objects are in a contrary Position to that of their Pictures on the *Retina*, in the present Case it would seem that the Order of Nature is inverted; for by this Experiment we ought to conclude, that the Object forms its Picture on that Side of the *Retina* on which it is, which is altogether contrary to all the Laws of Optics, and to all our other Experiences.

For explaining this *Phænomenon*, (See *Fig.* 7. PLATE I.) where the Candle A is the small luminous Object, BC*de* the Eye, and *a* the Point of Concourse, where the Rays AB, AC, *&c.* that come from the Point A, are united behind the *Retina*; these Rays being cut by the *Retina* before their Re-union, will thereon form the large Image *ed*, which, by Reason

Reaſon of the round Figure of the Pupil will alſo be round, whence the Candle itſelf will likewiſe appear round, and of a Bigneſs anſwerable to the Bigneſs of its luxuriant Image; for by means of the Impreſſion at *e*, it will be ſeen at E in the right Line *ex*E, which being drawn thro' the Centre of the Eye *x*, is perpendicular to the *Retina* at the Point *e*; and by means of the Impreſſion at *d*, it will be ſeen at D in the right Line *dx*D; which being drawn thro' the Centre of the Eye *x*, is alſo perpendicular to the *Retina* at the Point *d*, and by means of the other Impreſſions made by the other Rays forming the circular Picture *ed*, it will be ſeen in the other Points of the Circle AED deſcribed about the Centre A, with the *Radius* AD or AE, and conſequently will appear big and round: And if, by the Interpoſition of the opaque Body F, the Ray AC be intercepted, there will be a Defect in the Picture at *d*, and conſequently a ſimilar Defect in the Appearance at D; and therefore if this ſame Body F be ſlowly moved from C to *f*, this Defect in the Picture will, by degrees, extend itſelf from *d* to *o*, by which a ſimilar Defect in the Appearance will be made to extend itſelf from D to A, inſomuch, that when the Extremity of the opaque Body F has, by moving from C to *f*, come to *f*, the Half of the

Picture at *do*, and the correſponding Half of the Appearance DA will be made to vaniſh, and the Candle will get a ſemicircular Appearance at AE: Whence it is eaſy to ſee, that the opaque Body itſelf F muſt appear as if it were on the contrary Side to that where it really is; for being moved from C to *f*, it will have the Appearance of a dark Shade that is moved from D to A.

10*mo*, The laſt *Phænomenon* that I ſhall notice, is the little Spots or Marks that long-ſighted People are ſo liable to ſee before their Eyes.

I have already inquired into the Cauſe of theſe Spots, and have ſhown that when the Eye ſees diſtinctly, no Spots will appear, unleſs there be ſome Defect in the *Retina* itſelf: But both in the *Viſus ſenilis* and *Myopia*, certain dark Spots or Marks will alſo be ſeen, when there are any ſmall opaque Marks on the *Cornea*, or anywhere within the Eye, that intercept ſome of the Rays in their Paſſage to the *Retina*; whence ſuch Eyes may be ſaid to ſee all their own Defects, which does not commonly happen when the Eye ſees diſtinctly, becauſe then the Rays that come from a Point in the Object are exactly united in a correſponding Point in the *Retina*; and therefore, tho' ſome of them be intercepted, yet that Point will be ſeen by means of thoſe that paſs;

paſs; yet if any ſuch opaque Spot be in the Back-part of the vitreous Humour where the Pencil is narrow, and intercept the whole Pencil, the correſponding Point of the Object will be darkened.

Theſe Spots or Marks are not all of the ſame Kind; there are ſome which may be called *fixt* and *permanent*, becauſe they do not change their Place with reſpect to the Axis of Viſion, and theſe muſt proceed from ſome Defect either in the *Retina* or *Cornea*, or in the vitreous and cryſtalline Humours. Others there are which may be called *fluctuating* and *inconſtant*, becauſe they are in conſtant Motion, and change their Place continually; and theſe muſt ariſe from ſome Corpuſcles floating in the aqueous Humour, which, being thin like Water, does not hinder them from changing their Situation; but whether they are fixt or moving, they muſt always appear like dark Marks or Defects in the Object, and that as well when they proceed from opaque Spots on the *Cornea*, or any where within the Eye, as when they proceed from the above obſerved Defects in the *Retina* itſelf.

And this leads me to explain another Kind of Spots that are very common in the preſbytical Sight, and which are not dark and ſhady, like thoſe that have been already accounted for,

for, but more bright and luminous than the Object itſelf before which they appear.

Theſe Spots appear beſt in looking to bright Objects at a conſiderable Diſtance, and are always of the ſame Colour with the Object before which they are ſeen. In the Middle their Colour is clear and ſtrong, which is ſurrounded by a dark and ſhady Border, not unlike the Knots of a poliſhed Fir-board. They are commonly accompanied with certain irregular Veins that proceed from each Spot, and which, as well as the Spots themſelves, change their Order and Diſpoſition. Theſe Veins are alſo of the ſame Colour with the Object, and being bright and luminous in the Middle, are likewiſe terminated by a dark and obſcure Edge; as may be ſeen at *Fig.* 8. PLATE I.

Theſe Spots and Veins do not always remain in the ſame Place, but change their Poſition with reſpect to the *Axis of Viſion*, according as the Eye is differently moved, being ſometimes in the *Axis of Viſion* itſelf, and at other times to the right or left of this ſame *Axis;* but when the Eye is kept fixed in the ſame Direction, they commonly deſcend gradually.

As for what concerns the Cauſe of theſe Spots and Veins, it ſeems evident, that,

1*mo*,

1*mo*, They muſt proceed from ſome Corpuſcles within the Eye, which are at Liberty to change their Place, and which therefore muſt be ſuppoſed to float in the aqueous Humour.

2*do*, Seeing theſe Spots do commonly deſcend when the Eye is kept fixed and immoveable, the Corpuſcles from which they ariſe muſt alſo deſcend, becauſe they are ſituated in the aqueous Humour before the Place of the Interſection of the Pencils; and conſequently they muſt be heavier than the aqueous Humour in which they ſwim.

3*tio*, Theſe Spots being more bright and luminous than the Object itſelf before which they are ſeen, they cannot be occaſioned by any opaque Corpuſcles, which, by intercepting the Rays, do caſt a Shade upon the *Retina*: For from ſuch Corpuſcles the Spots would appear like Defects or dark Marks on the Object; as has been ſhown above.

What therefore ſeems to bid faireſt for producing theſe Spots and Veins, is ſmall, denſe diaphanous Particles and Filaments, that ſwim in the aqueous Humour before the Cryſtalline; for ſuch Particles and Filaments, by reaſon of their Denſity and Weight, will fall downward when they are left to themſelves, and are not diſturbed by the Motion of the Eye, and by their greater refractive Power, and the Figures of their little Surfaces, they will

will produce these luminous Spots and Veins, terminated by dark and shady Borders. For the Rays of Light which pass through these dense Particles, by being more refracted, will meet sooner behind the Crystalline than the Rays that pass by, and do not meet with such Particles; whence if the Conformation of the Eye be such as renders it presbytical, the Rays of Light that come from the several Points of the Object will not converge to so many other Points in the *Retina*, but behind it, by which the Pictures on the *Retina*, and the Vision caused thereby, will be rendered more dark and obscure; but the Rays which pass thro' these dense Grains and Filaments, by having their Refraction increased, will be made to meet nearly at the *Retina*, where they will form small luminous Spots and Veins surrounded with dark and shady Borders; just as a convex Glass, when exposed to the Sun, forms its luminous *Focus* in the Middle of a very strong Shade with which it is environed. For as Light is not generated whenever we see it increased, it is by robbing some other Part of its Light, or by bringing the Light that should have been diffused over some other Part to the more enlightened Place: When therefore the Rays of Light that pass thro' these dense Particles and Filaments are so refracted as to conveen at the *Retina*, and paint thereon

thereon ſmall luminous Spots and Veins, theſe Spots and Veins will be terminated by a dark and a ſhady Edge; becauſe the Light which ſhould have illuminated the Edge is now made to fall on the luminous Picture. And thus you ſee, how, in the preſbytical Eye, ſmall luminous Spots and Veins, incompaſſed with dark and ſhady Borders, may be painted on the *Retina*, and how, from ſuch Pictures, ſimilar and like Spots and Veins will be ſeen moving before the Object.

Theſe Spots are obſerved to change their Figures ſometimes in two or three Hours; at other times not in two or three Days, and to appear more numerous at one time than another.

I have ſaid, that when they appear to deſcend, as they commonly do when the Eye is kept fixt in the ſame Direction, the Particles and Filaments producing them muſt alſo deſcend, becauſe ſituated in the aqueous Humour before the Place where the Pencils interſect each other within the Eye; and for the ſame Reaſon, ſhould theſe Spots appear to aſcend, which is indeed uncommon, the Particles producing them muſt alſo aſcend, and conſequently muſt be lighter than the aqueous Humour. They muſt therefore be ſuppoſed to be of an oily ſulphureous Nature; for being of this Nature they will not only aſcend, but by their greater refractive Power, they will caſt their diſtinct

distinct Images upon the *Retina*, for producing those luminous Spots and Veins; for that oily and sulphureous Substances, tho' less dense than Water, have a stronger refractive Power, is evident from the Observations of the incomparable NEWTON, who, in his admirable *Treatise of Optics*, has given us an exact Table shewing the Refractions of almost all Kinds of Bodies, by which it appears that the refractive Power of unctuous and sulphureous Substances is two or three times greater in respect of their Densities, than the refractive Powers of Glass, and other terrestrial alcalizate Concretes, and that Rain-water, with which the aqueous Humour may be supposed to agree, has a refractive Power in a Middle Degree between those two Sorts of Substances.

§ 19. From what has been now said concerning the *Phænomena* that are peculiar to the *short* and *long Sight*, it is easy to deduce the many Advantages that accrue to us from the Motion of the crystalline Humour; for it being by the Motion of this Humour that our Eyes are fitted for seeing distinctly at different Distances, had we been denied the Power of changing its Situation, there could have been no distinct Vision, but at one determined Distance, either great, middle, or small, according to the particular Disposition of our Eyes; and with respect to all Objects at a greater or lesser Distance, the Sight would have

have been *myopical* or *preſbytical*, and conſequently would have been liable to all the Symptoms, Defects and Inconveniencies above explained. But,

§ 20. 2*do*, Beſides the Advantage we receive from the Mobility of the Cryſtalline, in enabling us to ſee diſtinctly at different Diſtances, there is yet another taken Notice of by the greateſt Part of our optical Writers, which conſiſts in enabling us to judge with more Certainty of the Diſtance of Objects.

There are ſix things whereby we are enabled to diſcover the Diſtance of Objects; all which I ſhall have Occaſion to explain hereafter, and therefore ſhall here only explain, how the Mind judgeth of Diſtance by that Diſpoſition of the Eye, that is neceſſary for ſeeing diſtinctly at different Diſtances.

We have already demonſtrated, that there can be no diſtinct Viſion, unleſs the Rays of Light, which are ſent from the ſeveral Points of the Object, be, by the Humours of the Eye, refracted and brought together in ſo many correſponding Points on the *Retina*: And that the ſame Conformation in the Eye is not able to perform this Effect, but muſt be changed by the Contraction of the *Ligamentum Ciliare*, which being ſenſible to us, becauſe it depends upon our Mind which regulates it, will enable us in ſome Meaſure to judge of Diſtances,

even with one Eye: As for inſtance, when I view an Object at ſeven Inches Diſtance, I diſtinguiſh its Diſtance by the Diſpoſition of the Eye, which at that Diſtance is not only ſenſible, but in ſome Sort uneaſy; and when the ſame Object is viewed at twenty ſeven Inches Diſtance, the Diſtance is ſtill perceived, becauſe the neceſſary Diſpoſition of the Eye is ſtill ſenſible, tho' no longer uneaſy. And thus you ſee, how with one Eye alone we judge of leſſer Diſtances, from the Change which happens in the Conformation of the Eye; but, as this Change in the Conformation of the Eye has its Limits, beyond which it cannot go, it can be of no Uſe in aſſiſting us to judge of the Diſtance of Objects placed without the Limits of diſtinct Viſion; which in my Eyes can reach no further than from ſeven to twenty ſeven Inches: But as the Object does then appear more or leſs confuſed according as it is more or leſs removed from theſe Limits, this Confuſion ſupplies the Place of the Motion of the Cryſtalline, in aiding the Mind to judge of the Diſtance of the Object, it being always eſteemed ſo much the nearer or further off, by how much the Confuſion is greater.

But this Confuſion has its Limits alſo, beyond which it can never extend: For, when an Object is placed at a certain Diſtance from the

the Eye, to which the Breadth of the Pupil bears no ſenſible proportion, the Rays of Light that come from a Point in the Object, and paſs the Pupil, are ſo little diverging, that they may, in a phyſical, tho' not mathematical Senſe, be looked on as parallel; and therefore the Picture on the *Retina* will not, to Senſe, become more confuſed, tho' the Object be removed to a much greater Diſtance.

What this Diſtance is to which the Diameter of the Pupil bears no ſenſible proportion, Authors are not agreed on, nor ſhall I at preſent take upon me to determine; but conſidering the Smallneſs of the Pupil, it is obvious, that it cannot reach any far Way; and conſequently this Confuſion in the Appearance of Objects can only aſſiſt us in judging of ſmall Diſtances.

CHAP.

## CHAP. V.

### *Of the Pupil and its Motions;*

AND

### *The Benefit we receive from the Pupil and these Motions.*

SECT. 1. IN ſpeaking of the Structure of the Eye, I obſerved, that the *Uvea* has a ſmall round Hole in its Middle, called the *Pupil*, thro' which the Rays muſt all paſs before they can get to the Bottom of the Eye, for painting the Images of external Objects upon the *Retina*; and therefore it is, that the whole Structure of this moſt curious and beautiful little Organ would have been in vain, and to no Purpoſe, had Nature forgot thus to perforate this Tunicle.

But, that I may the better explain the Uſe of the Pupil, and the Benefits which our Sight receives from it, I ſhall conſider theſe three Things; 1*ſt*, Its *Magnitude*; 2*dly*, Its *Figure*, and 3*dly*, Its *Motions*.

§ 2. As to the *firſt*, the *Magnitude* of the Pupil; we all Experience, that it is preciſely ſuch

ſuch as is neceſſary for admitting that Quantity of Light which perfect Viſion requires. Had it been much larger, then the tender Subſtance of the *Retina* would have been fatigued, dried, burnt, or otherwiſe hurt, upon a thouſand Occaſions, by the too great Quantity of Light which would have been collected upon it; for the Humours of our Eyes perform much the ſame Effect with that of a convex *Lens* or Burning-glaſs, by refracting the Rays of Light, and making them converge to a Point in the *Retina*; and therefore it is that thoſe Creatures who have the Pupil extraordinary large for enabling them to ſee in the Night-time when the Light is weak, ſuch as the Bat-bird, the Owl, and other Night-Birds, cannot bear the Light of Day, but are obliged to abſcond themſelves in ſome dark Place till Night returns.

But, beſides this, had the Pupil been much larger than it is, the Eye would not have been a *Cellula Obſcura*, but would have been enlightened by the Light proceeding from all the Objects round about us, and to which the Sight is not directed; and being thus enlightened, the Pictures on the *Retina*, by being mixed with this foreign Light, would have been rendered very obſcure and indiſtinct; and conſequently the Viſion produced by theſe obſcure and indiſtinct Pictures, would alſo have

have been obſcure and indiſtinct; for, as in a *Camera Obſcura*, the Pictures are always the moſt lively and perfect when the *Camera* is keept dark, and no Light is allowed to enter it, but what comes from the Object forming the Picture; ſo, in the Eye, the Pictures will always be the moſt lively and perfect when no Light enters the Eye to mix with the Picture, but what comes from the Object in view, and conſequently the Sight produced by theſe Pictures will then alſo be the moſt diſtinct and perfect.

But this is not all; for, had our Pupils been much larger than they are, our Sight would, on ſeveral other Accounts, have been a good Deal leſs diſtinct than it is at preſent. It has already been ſhown, that there is always a ſmall Degree of Confuſion in our Sight, ariſing from the Sphericalneſs of the Surfaces of the refracting Humours, and ſtill a greater Degree of Confuſion ariſing from the different Refrangibility of the Rays; but the greateſt Confuſion of all is, that which proceeds from the too great Diſtance or Proximity of Objects: For, according as the Object is nearer or farther off, the Conformation of the Eye muſt be changed, that the Picture on the *Retina* may be made as diſtinct as poſſible; but this Change of Conformation has its Limits, beyond which it cannot go, and therefore all Objects

Objects that are placed beyond these Limits must appear more or less confused, according as they are more or less removed from these Limits to which the Eye can accommodate itself. Now, from what I have said before on these Heads, which I shall not now repeat, it is obvious, that the Indistinctness proceeding from all these Causes will be greater or less, according as the Pupil is greater or smaller; and therefore, had our Pupils been much larger than they are at present, we should not have seen so distinctly as we now do.

On the other hand, had the Pupil been much smaller, we would then indeed have seen more distinctly, but the Light would not have passed in that Quantity which is necessary for painting the Images of Objects upon the *Retina* with sufficient Strength and Brightness; and therefore all Vision would have been rendered faint and obscure. From all which, it is easy to see, why Nature has thus perforated the *Uvea* with a Hole of such a determined Degree of Magnitude, as is answerable to the Degree of Sensibility, and Delicacy of the *Retina*, and to the Occasions we have for a perfect Sight, by having the Images on the *Retina* made as perfect and distinct as possible.

§ 3. 2*dly*, What falls next to be considered, is the *Figure* of the Pupil. This in Man, as well

well as in the greateſt Part of other Animals, is round or circular; which being the moſt capacious of all Figures, muſt tranſmit the greateſt Quantity of Light, by which means the Pictures on the *Retina*, and the Viſion cauſed thereby, will be ſtronger and more lively than they could have been, had the Pupil been of any other Figure.

By means of this Figure, the Pictures on the *Retina* are alſo rendered more diſtinct; for ſince, as I have before obſerved, no ſpherical Surface can accurately refract all the Rays of a large Pencil to a ſingle Point, but only thoſe that go pretty near its *Axis*, there muſt always be ſome ſmall Confuſion in theſe Pictures, ariſing from the Sphericalneſs of the Surfaces of the refracting Humours, and ſtill a greater Confuſion from the too great Diſtance or Proximity of Objects. But this Confuſion will be leſſened by the ſpherical Figure of the Pupil, becauſe all the Rays are thereby brought as near the *Axis* of the Pencil as poſſible; whereas, had the Pupil been of any other Figure, ſome of the Rays belonging to each Pencil would have been further removed from its *Axis*, by which the Pictures on the *Retina* would have been more confuſed and indiſtinct. And this is the Reaſon, why, when the Pupil is long or elliptical, as in Horſe, Cows and Sheep, or in Form of a Fiſſure,

Fiſſure, as in Cats; ſuch Creatures cannot ſee ſo diſtinctly as Man and other Animals, having a round Pupil; but it was needful, that in them the Pupil ſhould be oblong, to ſerve other uſeful Purpoſes: as ſhall be explained hereafter.

Another Reaſon for the Roundneſs of the Pupil is, that the Eye might thereby be enabled to ſee equally well every way, above and below, and on both Sides: Whence in Man, and in all other Creatures, who have Occaſion to ſee every way equally, this Aperture is always circular; but in Oxen, Goats, Horſe, Sheep, and divers other Creatures, whoſe chief Buſineſs is to ſeek their Food with their Heads bowed down towards the Earth, and who therefore have only Occaſion to ſee Objects immediately before them, and on each Hand, their Pupil is always oblong or elliptical, having its greateſt Diameter placed towards the Angles of the Eye, that it may the better receive the Rays which come from Objects on either Side; which is an admirable Proviſion for theſe Creatures to ſee laterally, and thereby to avoid Inconveniencies, as well as help them to gather their Food on the Ground both by Day and Night. But of this more hereafter, when I come to account for the different Conformations of the Eyes in different Animals.

§ 4. The *laſt* Thing remarkable in the Pupil, is its *Motions*: For this Aperture has no fixt determined Meaſure, but varies in its Magnitude according as Circumſtances vary.

GALEN, of old, obſerved this; but being ignorant of the Laws by which theſe Motions are governed, he thought that the Pupil had no Motion, but that of dilating itſelf, when the other Eye was ſhut or loſt, and again contracting itſelf, when the Eye was opened or recovered. That this was GALEN's Opinion, appears from the 5th Chapter of his 10th Book *De Uſu Partium*, where he alſo accounts for this Dilatation of the Pupil, from the whole of the viſive Rays or Spirits, which, according to him, conſtantly ſtream forth from the optic Nerves, thro' both Eyes, for cauſing Viſion, being now all determined into the ſeeing Eye, for ſtrengthening its Sight, and ſupplying the Want of the other: For, from this greater Flow of Spirits, thro' the ſeeing Eye, he ſuppoſed the Pupil was preſſed open and enlarged; and tho' he was greatly miſtaken as to the Cauſe of this Dilatation, yet he was thereby happily led, to make a very judicious and uſeful Prognoſtic in the Caſe of Cataracts; for he tells us (*de Sympt. Cauſ. Lib.* 1. *Cap.* 2.), That if, in this Diſeaſe, the Pupil of the one Eye dilates, when the other Eye is ſhut, there is Hopes from the Operation, becauſe the

Nerves

Nerves are ſound and pervious, but if it does not dilate, all Hopes are loſt, becauſe this is a Sign that the optic Nerves are affected.

That this Prognoſtic is indeed true, we are taught by Experience: But it does not from thence follow, that the Pupil is dilated by any Flow of Spirits ſtreaming forth from the optic Nerve, but only that the *Retinæ* and Nerves have become paralytic and inſenſible, when the Pupils do not move; for when both Eyes are open, the Light that paſſes to the *Retinæ* thro' the demi-opaque Cryſtallines, cauſes both Pupils to contract in proportion to the Senſation of Light affecting the *Retinæ*: But when one of the Eyes is ſhut, the *Retina* of that Eye will not any longer be affected by Light, and therefore its Pupil will dilate, and being dilated, the Pupil of the other Eye will alſo dilate; becauſe the Pupils of both Eyes always ſympathize with each other in their Motions; as ſhall be explained afterwards: But when the *Retinæ* are paralytic and inſenſible of the Light, both Pupils will always keep dilated to their utmoſt Extent, as well when both Eyes are open, as when one of them is ſhut, becauſe there is then nothing that ſhould influence us to contract them; and therefore this Want of Motion in the Pupils is a Sign that the *Retinæ* and Nerves have become paralytic and inſenſible,

ſible, which muſt render the Operation uſeleſs; but it by no means proves, that the Pupils are dilated by any Flow of Spirits ſtreaming forth from the optic Nerves, as GALEN imagined.

§ 5. In this opinion, that the Pupil has no Motion but when the other Eye is ſhut or loſt, GALEN was followed by all Phyſicians, as well as Philoſophers, till the diligent Anatomiſt, FABRICIUS *ab Aquapendente*, Profeſſor at *Padua*, and Succeſſor to the great FALOPIUS, by obſerving the Eyes of a Cat, found, that the Pupil not only dilated and contracted itſelf, when one of the Eyes was ſhut, but alſo when both were open.

This unexpected Diſcovery did at firſt very much ſurpriſe AQUAPENDENT, becauſe it run croſs to what every body then believed, from the Authority of GALEN; more eſpecially that he alſo obſerved, that the Pupils of both Eyes contracted and dilated frequently in a very ſhort Space of Time, tho' the Light continued the ſame: So that he juſtly ſuſpected that theſe Motions were altogether voluntary, like that of other Muſcles, tho' he was at a loſs to account for it, as he could find no Muſcle for performing theſe Motions; and he does not ſeem to have known any thing of the circular and longitudinal muſcular Fibres of the *Uvea:* But having communicated theſe Obſervations

ſervations to ſome of his learned Friends, and in particular to the famous Father PAUL of *Venice*; this learned Father found, from repeated Experiments, that the Pupil, not only in Cats, but alſo in Man, and all other Creatures, always contracted itſelf, when the Eye was expoſed to a bright Light, and again dilated itſelf when the Light was faint and languid: And this he always obſerved, as well when both Eyes were open, as when one of them was ſhut; and therefore this learned Father juſtly deſerves the Honour that is due to ſuch a noble and uſeful Diſcovery.

I know ACHILLINUS, in his *Annotationes in Mundini Anatomiam*, publiſhed *ann.* 1522, makes mention of the ſame *Phænomenon*, long before it had been obſerved by Father PAUL, as MORGAGNI has noticed; yet it would appear, that all Phyſicians, as well as Naturaliſts, either overlooked this Paſſage, or imagined the *Phænomenon* to be preternatural. This much at leaſt is certain, that the famous MONTANUS (who, after having taught Medicine at *Padua* for twenty Years, died in the Year 1551,) having obſerved, in two of his Patients, that the Pupil dilated in a dark Light, and contracted in a bright Light, was ſo far from looking on theſe *Phænomena* as natural, that he ſays they are Signs of a weak Sight, and attributes them

to

to a Thickneſs of the Spirits (See his *Conſultationes*, N° 91. and 92.) And, as FABRICIUS *ab Aquapendente*, in his Treatiſe *de Oculo*, *Part* 3. *Chap.* 6. publiſhed in the Year 1603, is the firſt after ACHILLINUS who makes Mention of this *Phænomenon* as natural, and aſcribes the Diſcovery of it to Father PAUL in the Manner above ſet forth; it would be unjuſt to deny him the Honour of the Diſcovery, tho' it might have been noticed before by others, and particularly by ACHILLINUS.

§ 6. But it is not enough to aſſert the Motions of the Pupil from the Authority of others; an experimental Proof of theſe Motions, and of the Laws whereby they are governed and conducted, will be expected: This therefore I ſhall endeavour to give, in the following Propoſitions:

## PROPOSITION I.

*All Animals have a Power of contracting and dilating their Pupils, as occaſion requires.*

This every Body knows, and it will further appear, from the Experiments and Obſervations to be mentioned below.

PROP.

## PROP. II.

§ 7. *The natural State of the Pupil is a State of Dilatation, and its Contraction a State of Violence, occaſioned by the Contraction of the circular Fibres of the* Uvea.

This, as I have before obſerved, is manifeſt from its being very large in a *Syncope*, Apoplexy, *Gutta Serena*, and for ſome time after Death, *&c.* for in theſe, and ſuch like Caſes, as the Eye is altogether inſenſible of the Light, ſo all the Muſcles and muſcular Fibres have loſt their Tone and Power of Contraction, and therefore the Pupil muſt of itſelf fall into that State which is moſt natural to it. But ſince, in all theſe Caſes, it is always found dilated, it follows, that this is its natural State, and that its Contraction is a State of Violence, introduced at the Command of our Will, and cauſed by the Contraction of its circular Fibres. And this is ſtill further confirmed by that dazzling Uneaſineſs which we all feel from ſtrong Light immediately after waking, when the Pupil may alſo be ſeen greatly enlarged: Whence, when we ſay a Man dilates his Pupil, nothing is meant, but that he no longer wills its Contraction, for the longitudinal Fibres of the *Uvea*, which had been extended

tended by the Contraction of the circular Fibres, when they are left to themſelves, will, by their natural Elaſticity, contract, and, by contracting, dilate the Pupil, more or leſs, according as the orbicular Fibres are more or leſs relaxed.

## PROP. III.

§ 8. *When the Light is ſtrong, or the viſual Object too luminous, we contract the Pupil for intercepting a Part of the Light, which otherwiſe would dazzle and hurt our Eyes.* But,

## PROP. IV.

§ 9. *When our Eyes are in no Danger of being hurt by the Light, and eſpecially if the Light is ſo weak, as to make but a faint obſcure Picture on the* Retina, *we enlarge this Aperture, that more Light may enter the Eye, for making a ſufficient Impreſſion on this Membrane.*

That theſe Propoſitions are true, we may gather from many Experiments; the following are very eaſy and convincing:

Cauſe a Man to ſit with his Face towards the Window, when the Sun ſhines, and deſire him to look towards the Sun, you ſhall then obſerve

obſerve the Pupil extraordinary ſmall; but if he turns his Eyes from the Light, or be gradually brought into a darker Place, ſo as leſs Light may enter the Eye, you ſhall obſerve the Pupil to dilate itſelf proportionably to the Faintneſs of the Light and Obſcurity of the Place.

The ſame thing will alſo happen if you place a Candle, or even a white or other bright Object before the Eyes, and gradually remove it from before them, by carrying it off ſideways; for you ſhall obſerve, that the Pupil dilates itſelf more or leſs, according as leſs or more Light is ſent into the Eye from the luminous or bright Object.

## PROP. V.

§ 10. *The Pupil contracts when the Object is near the Eye, for making the luminous Pencils narrow and leſs diverging, that the Picture on the* Retina *may be rendered more diſtinct.*

I have already obſerved, that when the Object is nearer than the neareſt Limits of diſtinct Viſion, the Rays that come from the ſeveral Points of the Object will not be united in ſo many correſponding Points in the *Retina*, but at ſome Place behind it: Where the Pi-

cture on the *Retina*, and the Vision thereby caused, will be confused and indistinct, still the more confused, the nearer the Object is to the Eye: But, by the Contraction of the Pupil, the little luminous Pencils, which have for their *Apex* a Point in the Object, and for their *Basis* the Aperture of the Pupil, will, by reason of their Acuteness, proceeding from the Contraction of the Pupil, take up a smaller Space on the *Retina*, still the smaller the more the Pupil is contracted; by which means the Confusion in the Picture will become less, and the Sight will be made more distinct, tho' less clear. This therefore is a good Reason for contracting the Pupil when Objects are nearer than the nearest Limits of distinct Vision; for they are thereby rendered more distinct, and at that Distance they are sufficiently luminous to be clearly enough seen, tho' the Pupil be a little contracted.

The Pupil may also contract in viewing Objects a little more remote than those nearest Limits; for tho' the Eye can adapt itself to that Distance, yet the Pupil may have good Reason to contract for rendering the Sight more distinct, and at the same time for avoiding that painful and laborious Contraction of the *Ciliary Ligament* which would be necessary to see the Object with sufficient Distinctness, and which, by being on the Strain, would

would be very fatiguing and uneaſy, eſpecially if the Object were to be viewed for any time together. But, if the Object is not ſufficiently luminous, this Ligament will not be eaſed of any Part of its Labour, in making the Object appear diſtinct, by the Contraction of the Pupil; for in this Caſe the Pupil will rather be enlarged to let in more Light, that the Object may be ſeen with ſufficient Brightneſs. And this is the Reaſon why Objects at a Diſtance, and beyond the fartheſt Limits of diſtinct Viſion, are ſeldom made more diſtinct by the Contraction of the Pupil; for the Light being commonly weak in diſtant Objects, the Pupil is ſo far from contracting, that there is often a Neceſſity that it be dilated to take in more Light, that the Object may appear ſufficiently bright and luminous; yet, when the Object is very bright, the Pupil will contract for rendering the Sight more diſtinct, at whatever Diſtance the Object be from the Eye; for then that Contraction anſwers two Purpoſes; one, to exclude an over-great Quantity of Light, which would be offenſive to the Eye; the other, to leſſen the Indiſtinctneſs. But that the Truth of this Propoſition may the better appear, I ſhall ſubjoin the following Experiments:

Cauſe a Man to take into his Hand a Pin, or any ſuch ſmall Object, and holding it at

a Diſtance from his Eye, while the other Eye is kept ſhut, let him bring the Pin gradually to within an Inch or two of the open Eye, looking upon it ſtedfaſtly all the while: When the Pin is at a Diſtance, the Pupil will be found dilated; but when it is brought near to the Eye, you will find the Pupil a good deal contracted.

The ſame thing may be obſerved, if two Pins be ſtuck in the ſame right Line in the *Axis* of Viſion; the one about an Inch or two, and the other at two or three Feet from the Eye; for when the near Pin is viewed, the Pupil will be ſeen contracted; whereas when the diſtant one is viewed, it will be ſeen dilated: And this Difference in the Magnitude of the Pupil can proceed from nothing but the different Diſtance of the Object, in the Contemplation of which the Sight is employed; for the Light ſent into the Eye is the ſame, whichſoever of the Pins the Eye contemplates.

From thoſe Experiments, which I have borrowed from that great Improver of Optics, the learned SCHEINER, it is evident, that the Pupil contracts at the near Approach of any ſmall Object, when we endeavour to ſee it diſtinctly. But,

PROP.

## PROP. VI.

§ 11. *The Pupil alſo contracts, for making the Picture more diſtinct, when the Object is too far off, and beyond the fartheſt Limits to which the Eye can accommodate itſelf, provided the Object be ſufficiently luminous; but, if otherwiſe, the Pupil will rather dilate, to take in more Light.*

This Propoſition is a natural Conſequence of the foregoing one; for if we contract the Pupil, that near Objects may appear diſtinct, we ought alſo, for the ſame Reaſon, to contract it, that diſtant Objects may appear diſtinct, unleſs when there is a ſuperior Reaſon for dilating it, as when the Light is too weak for making a ſufficient Impreſſion on the *Retina*. This is indeed commonly the Caſe in diſtant Objects, which therefore are ſeldom made more diſtinct by the Contraction of the Pupil; for it is a Miſtake to think, that, upon ſeeing an Object confuſedly, the Pupil does always contract itſelf to the leaſt Size it is capable of: The Degree to which the Pupil contracts, does in ſome Meaſure indeed depend on the Senſation of Confuſion in the Object; but, as ſhall be preſently ſhown, it depends yet more upon the Degree of Light; and in a faint Light it is frequently greatly dilated,

dilated, tho' the Object be very confuſed and indiſtinct.

## PROP. VII.

§ 12. *The Contraction of the Pupil depends more upon the Strength of Light than upon the Senſation of Confuſion in the Object.*

Dr. JURIN has proved this in the following Manner: "By Day-light, take any Book, "and ſtanding about the Middle of a Room "with your Back to the Window, hold the "Book ſo near, as the Letters may appear "indiſtinct, and yet not ſo much but that "you can read, tho' with ſome Difficulty; "then turn your Face to the Light, and the "Book will be read with more eaſe. Again, "holding the Book at the ſame Diſtance "from your Eye, go into the darkeſt Part "of the Room, and ſtanding with your "Back to the Light, you will find the Book "not at all legible; but, upon coming to the "Window with your Face to the Light, "you will be able to read, eſpecially if "the Sun ſhines, with great Eaſe and Di-"ſtinctneſs.

"Alſo a Perſon who has been obliged for "ſome Years to uſe Spectacles in reading, "will, in the Sun-ſhine, be able to read very "eaſily without them".

From

From theſe Experiments, it appears, that in a ſtrong Light the Pupil contracts to a greater Degree, than it can be made to do by the Senſation of Confuſion only, and conſequently, that it is a Miſtake to think, that, upon ſeeing an Object confuſedly, the Pupil does always contract itſelf to the leaſt Size it is capable of.

The following Experiment is alſo very convincing: Let a Perſon ſitting in the Middle of a Room, with his Face to the Window, when the Sun-ſhines, view an Object attentively placed betwixt his Eye and the Sun, and let the Object be either too far off or too near for diſtinct Viſion; then let the Window-ſhut be ſo far cloſed, as to hide the Sun and render the Room ſomewhat darker; when the Room is thus a little darkened, the Pupil will be found dilated, tho' the Object he contemplates be indiſtinct, becauſe placed without the Limits of diſtinct Viſion, to which the Eye can accommodate itſelf. But when the Window-ſhut is again opened, ſo as the Eye may receive the direct Light of the Sun, the Pupil will be found greatly contracted, tho' the Object he views be brought within the Limits of diſtinct Viſion, and conſequently be ſeen diſtinctly.

From this Experiment, it is evident, that the Pupil is ſo far from contracting itſelf to the

the leaſt Size it is capable of, upon ſeeing an Object confuſedly, that, on the contrary, it dilates conſiderably when the Light is faint and languid, even when the Object is confuſed and indiſtinct; and it is alſo evident, that the Contraction of the Pupil depends more upon the Strength of the Light than upon the Senſation of Confuſion in the Object; for the Pupil, which was pretty large when the Eye ſaw the Object confuſedly in the faint Light, contracts itſelf upon admitting the Light of the Sun, as well when the Object is ſeen diſtinctly, as when it is ſeen confuſedly.

And of the ſame Kind with this Experiment is alſo that which followeth: Place a Candle at ſuch a Diſtance from you, as that, when it is viewed in the Night-time, it may appear a good deal larger than it ought, becauſe it is too remote for diſtinct Viſion, and becauſe the Pupil is then much dilated, which muſt greatly increaſe the Magnitude of the Picture upon the *Retina*; if this ſame Candle be viewed in Day-light, or even if it be viewed by Night from a well lighted Room, or if a Flaſh of Lightning ſhould happen at the Time it is viewed, it will not appear much bigger than it ought, by reaſon of the Contraction of the Pupil, which corrects

corrects the Luxuriancy of its Picture upon the *Retina*.

This Experiment I noticed before; but as it ſerves to demonſtrate the Doctrine now before us, the Reader will forgive me for mentioning it again in this Place.

## PROP. VIII.

§ 13. *The Pupils of both Eyes ſympathize with each other in their Motions, ſo that when the one Pupil is contracted, the other alſo contracts, and when it is dilated, the other alſo dilates.*

This is a fundamental Law in the Motions of our Pupils; the not conſidering of which, has been the Occaſion of many groſs Overſights and dangerous Miſtakes in Practice; as might eaſily be ſhewn, were this a proper Place for ſuch Digreſſions.

That the Pupils ſympathize thus in their Motions, will be evident from the following Obſervations: Let a Man, having a *Gutta Serena* in one of his Eyes, turn his Face to the Light, the Pupil of the diſeaſed Eye will not be found much enlarged, while the other Eye is open and expoſed to the Light; but if the whole Eye be ſhut, the Pupil of the diſeaſed Eye will dilate itſelf greatly: The Reaſon of this is evident; for when the whole

Eye is open, its Pupil will contract, by reaſon of the Senſation which the Eye has of the Light which enters it; but when it is ſhut, the Pupil will dilate, becauſe there is then nothing that ſhould cauſe us to contract it; and therefore, tho' the diſeaſed Eye be altogether inſenſible of Light, and conſequently cannot be influenced by it, yet, as its Pupil has been in uſe of moving uniformly with the other, from which a habitual and cuſtomary Connection has grown up betwixt their Motions, which makes it impoſſible for us to move them differently, the Pupil of the diſeaſed Eye muſt follow the Motion of the other Pupil; and conſequently muſt dilate when the ſound Eye is ſhut, and contract when it is open.

And the ſame Uniformity in the Motions of the Pupils may alſo be obſerved, when both Eyes are kept open, and more Light and leſs Light is made to ſhine upon them alternately; for tho' the diſeaſed Eye, by reaſon of its being altogether inſenſible of the Light, continues quite immoveable in all Lights, when the ſound Eye is kept ſhut; yet, when both Eyes are open, the Pupil of the diſeaſed Eye follows the Motion of the other, and dilates and contracts according as leſs or more Light ſhines upon the ſound Eye.

This Sympathy and Connection betwixt the Motions of our Pupils, is a thing that was known

known to MAITRE-JEAN; for having told us, that, in the *Gutta Serena*, the Pupil is always immoveable, he afterwards explains this, by telling us, that it is not abſolutely ſo; and that, when one of the Eyes is only affected, the Pupil of the diſeaſed Eye follows the Motion of the other, and contracts and dilates according as more or leſs Light ſhines upon the ſeeing Eye, and according as the viſual Object is nearer or farther off (*Maladies de l'Oeil, Part.* 2. *Chap.* 4.) It is therefore ſomewhat ſurpriſing, that this ſame Author ſhould, in the very ſame Place, affirm, that, in the *Gutta Serena*, the Pupil is no larger than what it is uſually, when we view Objects at a moderate Diſtance; for, if when one of the Eyes is only affected, the Pupil of the diſeaſed Eye dilates more or leſs, according as the other Eye is leſs or more affected by Light, it follows, that the Pupil of this diſeaſed Eye muſt dilate ſtill more when the other Eye is ſhut, or, which is the ſame thing, when, from an Obſtruction in the Nerve, it has become inſenſible of the Light which enters it; it therefore ſeems ſomewhat ſtrange, that ſo knowing an Occuliſt as MAITRE-JEAN ſhould have fallen into this Miſtake, ſo contrary to his own Principles, as well as to Experience. But, I apprehend, that he was unwarily led into it, by obſerving the State of the Pupil, when one of the Eyes was only affected,

affected, and when at the ſame time the other Eye was expoſed to a pretty bright Light. But ſurely, had he reflected on that Sympathy which he himſelf had obſerved in the Motions of our Pupils, he might eaſily have corrected this Miſtake; for the natural State of the Pupil being a State of Dilatation, and its Contraction a State of Violence, introduced at the Command of our Wills, for moderating the Impreſſion on the *Retina*, when the Senſation of Light is too ſtrong, it is obvious, that, in the *Gutta Serena*, the Pupil muſt be dilated, becauſe, the *Retina* being altogether inſenſible of the Light, there is nothing that can excite the Mind to contract it; and therefore, when both Eyes are affected with this Diſeaſe, both Pupils muſt keep conſtantly dilated and immoveable in all Degrees of Light, as is agreeable to Experience; and tho', when one of the Eyes is only affected, the Pupil of the diſeaſed Eye is not found much enlarged while the other Eye is open and expoſed to Light; yet this does not prove that the Pupil is not dilated in the *Gutta Serena*, but only that this Dilatation, which is the proper State of the Pupil in this Diſeaſe, is not allowed to take place, when the Pupil of the ſeeing Eye is made to contract by the Light that enters it: For when the ſeeing Eye is ſhaded from the Light, the Pupil of the diſeaſed Eye will be greatly dilated, juſt as

when

when the ſeeing Eye is ſhut; and this Dilatation will not be varied, by making more or leſs Light ſhine upon the diſeaſed Eye, but will be varied continually, according as more or leſs Light ſhines upon the ſeeing Eye.

This Sympathy betwixt the Pupils may alſo be proved, by obſerving the State of the Pupils when both Eyes are ſound.

For this Purpoſe, let any Perſon ſit near the Middle of a Room, with his Face to the Window when the Sun ſhines, and let a Dale-board, or thin Book, be applied betwixt the Eyes, with its Edge reſting on the Fore-head and Noſe; and let this Dale-board or Book be placed in ſuch Manner as it may hide the Window from his Right-eye, while with the Left-eye he ſees the whole Window without any Impediment: This done, while he fixes his Eyes on ſome Point of the Room near to the Right-ſide of the Window (which Point muſt be taken ſo as it may be ſeen by both Eyes), let him bring his Hand before his Left-eye, ſo as the Window may alſo be hid from that Eye. While the Hand continues before the Eye, the Pupil of the other Eye will be ſeen dilated; but when the Hand is removed from before the Eye, the Pupil of this other Eye will be found a good deal contracted.

Here the Eyes continue fixed on the ſame Object, ſo that the Pupil has no Occaſion to vary

vary on account of the different Distances of the Object; and as the Light that shines upon the Right-eye is always the same, its Pupil will not be made to vary by any Difference in the Light that enters it; and yet this same Pupil dilates and contracts, according as the Pupil of the other Eye is made to dilate and contract by the different Degrees of Light that shines upon it: And therefore this Dilatation and Contraction in the Pupil of the Right-eye can proceed from nothing but that Sympathy and Connection that Use and Custom have established betwixt our Pupils, which makes it impossible for us to contract or dilate the one, without at the same time contracting and dilating the other.

I observed before, from GALEN, that, when one of the Eyes is shut, the Pupil of the other dilates considerably, which is a further Confirmation of this Doctrine; for since no Light passes to the *Retina* of the shut Eye, its Pupil must dilate, and being dilated, the Pupil of the other Eye is made to follow its Motion, and is therefore found dilated; as GALEN observed.

From this Doctrine many odd and surprising *Phænomena*, to be observed in the Diseases of the Eyes, might easily be accounted for. But I shall here only mention one, which frequently occurs in Practice. It is as follows:

A Person having a Cataract in one of his Eyes, if, after keeping both Eyes shut for some

ſome little Time, he ſhall open the diſeaſed Eye, while he ſits oppoſite to the Window, that you may the better ſee what happens; you ſhall obſerve, that the Pupil of this diſeaſed Eye, is at firſt very large, and that it immediately contracts to a certain Degree. After the Pupil has done with contracting, cauſe the perſon to open the ſound Eye, and you ſhall then obſerve that the Pupil of the diſeaſed Eye contracts yet more than before, tho' not quite to that Degree that the Pupil of the ſound Eye is contracted to.

From the Principles I have laid down, ſuch Appearances are no longer Riddles; for when both Eyes are ſhut, the Pupils muſt dilate; becauſe that is their natural State; and there is nothing that can influence us to contract them while the Eyes continue ſhut: And therefore, when the diſeaſed Eye is opened, the Pupil will be found dilated; but, after that the Eye is opened, the Pupil cannot continue long in that dilated State, by reaſon of the Light that enters the Eye, which muſt make the Pupil contract; for tho' in Cataracts the Opacity of the Cryſtalline is ſuch as deprives the Eye of Sight, yet it does not altogether hinder the Rays from getting to the *Retina*; as I ſhall have Occaſion to explain afterwards: The Light therefore which gets to the *Retina* muſt cauſe the Pupil to contract, tho' not to that Degree

that

that it is afterwards made to contract when the ſound Eye is opened; for the ſound Eye being perfectly tranſparent, intercepts none of the Light, and therefore its Pupil will be made to contract more than the Pupil of the other Eye, which, by reaſon of the Cataract, is leſs affected by the Light; and the Pupil of the ſound Eye being thus more contracted, the Pupil of the diſeaſed Eye will be made to contract more than before, by reaſon of that Sympathy which connects the Motions of our Pupils. But, tho' the Pupil of the diſeaſed Eye is made to contract more than before when the ſound Eye is opened, yet it does not contract altogether ſo much as the Pupil of the ſound Eye does; as ſhall be explained in the next Propoſition; to wit,

## PROP. IX.

§ 14. *Tho' our Pupils ſympathize with each other in their Motions, yet they are not thereby made to contract or dilate equally.*

Many Experiments and Obſervations might be brought for illuſtrating and proving this Propoſition; of which I ſhall only mention a few:

Let a Perſon, ſitting with his face towards the Light, ſhut one of his Eyes, the Pupil of

of the other Eye, tho' it dilates conſiderably, yet it will not dilate altogether ſo much as the Pupil of the ſhut Eye; for, upon opening the ſhut Eye; you can ſee that its Pupil, immediately after the Eye is opened, is ſenſibly larger than the Pupil of the other Eye.

The Reaſon of this is obvious; for when one of the Eyes is ſhut, its Pupil muſt dilate, becauſe no Light enters the Eye; wherefore the Pupil of the open Eye, which, by reaſon of the Sympathy that there is betwixt the Pupils, endeavours to conform itſelf to the Pupil of the ſhut Eye, muſt alſo dilate and become larger; yet it does not dilate to that Degree that the Pupil of the ſhut Eye dilates to, becauſe, at the ſame Time that it is influenced by the Principle of Sympathy to conform itſelf to the Pupil of the ſhut Eye, it is alſo influenced by another Principle which acts in oppoſition to that Principle; for the Light that ſhines upon the Eye, ſollicits the Pupil to contract, and therefore the Pupil of this open Eye will not be quite ſo much dilated as the Pupil of the ſhut Eye.

In like manner, the Pupil of the ſhut Eye will not, while the other Eye is open, be dilated to that Degree that it would dilate to if this other Eye were ſhut; for, while it endeavours to dilate to its greateſt Extent, becauſe

it is intirely deprived of Light, it is at the ſame time influenced to contract, by the Contraction of the Pupil of the open Eye, whoſe Motions it alſo endeavours to follow; for, as in *Algebra* negative and poſitive Quantities deſtroy each other, and as in Mechanics oppoſite and contrary Impulſes make the Body move in the Direction of the greater Impulſe, not with a Motion proportional to that greater Impulſe, but with a Motion proportional to the Difference of thoſe Impulſes; ſo in our Pupils, when their Motions are influenced by different and oppoſite Cauſes, they muſt move, not in proportion to any one of thoſe Cauſes, but in proportion to their Difference; and therefore, tho' our Pupils ſympathize with each other in their Motions, yet they will not thereby be made to contract or dilate equally.

The ſame Thing may alſo be proved, by making a Man to ſit with his Side to the Window in a good Light, ſo as the Light may freely ſhine upon one of his Eyes, while, at the ſame time, the other Eye is ſhaded from the Light by the Projection of the Noſe; for, in the Eye that is ſhaded, the Pupil may be ſeen more dilated than the Pupil of the other Eye, upon which the Light ſhines without any Impediment.

This

This Experiment was taken notice of by PLEMPIUS, tho' not with a View to prove the Propoſition now before us: For he was intirely ignorant of that Principle of Sympathy, whereby the Motions of our Pupils are governed. His Words are: *A varietate autem lucis variare quoque pupillæ foramen, cuivis patere poteſt: Nam ſi hominis latus unum luci obvertas ita, ut uno oculo lucem excipiat, conſpici poteſt clarè, pupillam luci obſervam alterâ eſſe ſtrictiorem, jucundo omnibus naturalis ſcientiæ cultoribus ſpectaculo*, (*Ophthalmograph. Lib.* 1. *Cap.* ii.)

But, to render this Experiment ſtill more ſenſible, it may be proper to place a ſmall Dale-board, or thin Book, betwixt the Eyes, ſo as the Shade that falls upon the Eye may thereby be made ſtronger.

This Doctrine is ſtill further confirmed from the Obſervation of M. DU FAY (*l' Hiſt. de l' Acad. Roy. ann.* 1735); for if one Eye be ſhut, and the other open, and if we thus enter into a dark Room, and then open both Eyes, we may perceive the weak Light of a Diamond with the Eye which was ſhut, which will not be ſeen by the other Eye, becauſe its Pupil is not ſo much dilated.

Many more Experiments and Obſervations of this Nature might be added. But, as I like not, without Neceſſity, to multiply Examples of the ſame Kind, I ſhall conclude with

with the following one from *M. de la* HIRE. This famous Academician tells us, (in his Diſſertation *Sur les differens Accidens de la Veüe*), That, after that one has for ſome Time viewed a very luminous Body thro' a Teleſcope, Objects may be obſerved to appear a great deal darker to the Eye that was employed in looking through the Teleſcope, than to the other that was kept ſhut. It is eaſy to make this Experiment in the Twilight, by looking alternately with both Eyes to a white Wall or Sheet of white Paper, after that one has viewed the Moon with a Teleſcope. The Reaſon of this *Phænomenon* can be nothing but the Contraction of the Pupil, occaſioned by the great Light; for the Brightneſs of the Object makes the Pupil contract as much as is poſſible; but the Pupil of the ſhut Eye will be much larger, becauſe it contracts only by Sympathy; and therefore it muſt allow more Light to enter the Eye, which muſt make the Object appear whiter to this Eye than to the other; and the Object appearing whiter to this Eye than to the other, is a clear Proof that its Pupil is larger, and conſequently that the Principle of Sympathy does not make our Pupils contract or dilate equally. But it is carefully to be obſerved, that if the white Wall or Paper that one looks at, after viewing the luminous Body with the Teleſcope, be ſtrongly illuminated, as with Day-

Day-light, the Experiment will not ſucceed; for the great Light of the Object will affect the *Retinæ* of both Eyes ſo ſenſibly that we cannot diſtinguiſh any Difference in the Impreſſions, or in the Senſations ariſing therefrom.

§ 15. Now, the Mechaniſm by which this Contraction and Dilatation of the Pupil is performed, conſiſts in the Diſpoſition of the muſcular Fibres of the *Uvea*; for, as we have before obſerved, in ſpeaking of the Structure of the Eye, the *Uvea*, beſides its membranous Fibres, has two Orders of muſcular ones; of which the one, being circular, ſurrounds and embraces the Pupil like a *Sphincter*. Theſe therefore, by contracting, muſt leſſen the Pupil more or leſs, as Circumſtances may require. The other Order of Fibres croſs theſe juſt now named at Right-angles; for they ariſe from the Circumference of the *Uvea* where it joins the *Choroides*, and paſſing ſtreight along the *Uvea*, like Rays drawn from the Circumference towards the Centre, are inſerted all round its inward Edge, where it forms the Pupil; and therefore, when they contract, the Pupil muſt be enlarged. But, ſince I have already demonſtrated, that the natural State of the Pupil is a State of Dilatation, both theſe Planes of Fibres muſt be *in Equilibrio* when the Pupil is dilated; and therefore, tho' the Pupil cannot

not be contracted, but by the muſcular Contraction of the circular Fibres, by which alſo the longitudinal ones will be extended; yet, in order to dilate the Pupil, no muſcular Contraction of the longitudinal Fibres will be neceſſary: All that is neceſſary, is, that the circular Fibres ceaſe to contract; for the longitudinal Fibres, which had been extended by the Contraction of the circular ones, will, by their natural Elaſticity alone, then return to their natural State, and by returning thus, will enlarge the Pupil more or leſs, according as the circular Fibres are more or leſs relaxed. And this is the Reaſon why the Pupil is ſo much dilated in the Apoplexy, *Syncope*, *Amauroſis*, in Time of Sleep, and for ſome Time after Death.

§ 16. M. Mery, *of the Academy of Sciences*, not being able to diſcover the circular Fibres of the *Uvea*, framed a Hypotheſis for explaining the Motions of the Pupil by means of the longitudinal Fibres alone; and being convinced, from the Dilatation of the Pupil in the *Gutta Serena*, *Syncope*, and after Death, that the natural State of theſe Fibres is to be contracted, and to hold the Pupil open, he ſuppoſed that the Pupil was contracted by an Elongation of thoſe Fibres, occaſioned by an Influx of animal Spirits into them; ſo that, according to him, as other muſcular Fibres are contracted by

by an Influx of Spirits; these of the *Uvea* are, on the contrary, lengthened by such an Influx, (*Mem. de l'Acad. ann.* 1704). But this Hypothesis being so obviously contrary to the usual Course and Tenor of Nature, has therefore been justly rejected by most Authors of any Character; and indeed, it would require some stronger Proof, than any thing that has been brought by M. MERY, to persuade us that the Action of muscular Fibres, which every where else consists in Contraction, does in the *Uvea* consist in Elongation.

§ 17. The chief Argument he brings for this, is his not having been able to discover any circular Fibres. But, by the same way of Reasoning, he might as well maintain, that the *Antennæ* of Flies, and the Limbs of Mites and other minute Animals, are not moved by Muscles or muscular Fibres; because such Muscles and Fibres are not to be seen in such Animals; and yet no Body doubts but the Limbs of the most minute Animal, and the *Antennæ* of Flies, are all moved by true Muscles, and muscular Fibres, as well as the Limbs and *Proboscis* of an Elephant; and therefore, tho' the circular Fibres of the *Uvea* were quite invisible, it would not from thence follow, that they are wanting, since their Effects are as much seen, as the Effects of muscular Fibres in the Limbs of minute Animals. And surely

ſurely it is more agreeable to the Analogy of Nature, to ſuppoſe ſuch circular Fibres, tho' they were ſuch as could not be diſtinctly ſeen, than to ſuppoſe that the Action of the longitudinal Fibres of the *Uvea* conſiſts in Elongation; of which not ſo much as one ſingle Inſtance or Example is to be found any where elſe in the wholeCompaſs of Nature.

§ 18. What further M. MERY adds in favour of his Doctrine, is all taken from the following Experiment, *viz.*

Let the Head of a living Cat be immerſed into Water, while at the ſame time its Head and Eyes are kept expoſed to the Sun, and you ſhall find that the Pupil, in place of being made to contract by the ſtrong Light, will be greatly dilated; whereas, on the contrary, ſo ſoon as the Cat is taken out of the Water, its Pupil will be made to contract by the ſame Light ſhining upon its Eyes.

M. MERY having alſo obſerved, that while the Cat's Eyes are under Water, the *Choroides* and its Veſſels, and the Entry of the optic Nerve, are all diſtinctly ſeen, and that they are not at all ſeen in the Air, concludes, that more Light enters the Eye, when the Eye is in the Water, than when it is in the Air; from which Difference in the Light, the *Choroides* becomes viſible in the former Caſe, and inviſible

ſible in the latter. The Reaſon he gives why more Light enters the Eye when under Water than in Air, is, the Roughneſs and Inequality of the Surface of the *Cornea*, which makes it reflect a good deal of the incident Light, when the *Cornea* is in Air; but in Water this Roughneſs being taken off by the Particles of the Water, which by filling up all the Inequalities, brings the Surface to a more exact Poliſh, leſs Light will be reflected, and more tranſmitted.

§ 19. From theſe Obſervations M. MERY concludes, that the Fibres of the *Uvea* are lengthened for contracting the Pupil, not by any mechanical Action of the Rays upon them, but by an Influx of animal Spirits into the Fibres themſelves. His Reaſoning is in Subſtance this:

Since (according to him) more Light enters the Eye, when the Eye is in the Water, than when is it in the Air, did the Elongation of the Fibres proceed from any mechanical Action of the Rays upon the Fibres, the Pupil would be more contracted in Water than in Air, which is contrary to Experience: On the other hand, ſuppoſing the Elongation of the Fibres to be cauſed by an Influx of Spirits, and this Influx to be occaſioned by the Light that paſſes into the Eye, yet (ſays he) when the Eye is under Water, theſe Fibres, in place of being

lengthened, will be contracted, notwithstanding the great Light that passes into the Eye; and that because, under Water, the Animal being hindered from Breathing, the Motion of the Spirits, which depends upon the Circulation of the Blood, and consequently on Respiration, must be interrupted, and therefore cannot extend the Fibres of the *Uvea*; which Fibres will therefore, by their natural Elasticity, contract, and, by contracting, enlarge the Pupil: Whereas, on the contrary, so soon as the Cat is taken out of the Water, the Pupil will be made to contract by the same Light shining upon its Eyes; because then the Motion of the Spirits is no longer interrupted, but are at Liberty to flow freely into the Fibres for contracting the Pupil more or less, in proportion to the Light that acts upon the Eye.

§ 20. This is in Substance what M. MERY advances on this Head. And, indeed, were it true, that the Pupil was made to contract by an Elongation of the longitudinal Fibres of the *Uvea*, it would not be difficult to shew, that this Elongation behoved to be performed by an Influx of Spirits, and not by any mechanical Action of the Rays themselves; and yet we are far from thinking that M. MERY's Reasoning proves this: And that for these Reasons:

1*st*,

1*ſt*, Tho' the Surface of the *Cornea* be ſuppoſed ſomewhat rough and unequal, yet being always kept wet with the Liquor that comes from the Lachrymal Gland, the Quantity of Light reflected by it, when the Eye is in the Air, will not exceed the Quantity reflected by the Surface of the Water when the Eye is under Water: For, to ſpeak properly, when the Eye is in the Air, it is not the *Cornea* itſelf, but the Surface of the Liquor with which it is moiſtened, that reflects the Light; and therefore nearly the ſame Quantity will alſo be reflected from the Surface of the Water when the Eye is in Water. This is contrary to the Opinion of M. Mery, who maintains that a great deal of Light is loſt on the *Cornea* in Air, and does not conſider that as much muſt be loſt on the Surface of the Water. But,

2*dly*, Tho' the *Choroides* be diſtinctly ſeen under Water, and not at all in Air, it does not from thence follow, that more Light enters the Eye in the former Caſe than in the latter; but only, that more of that Light paſſes to the Bottom of the Eye, becauſe of the Dilatation of the Pupil: For as Objects in a Chamber are ſo much the more illuminated and better ſeen, that the Windows are large, ſo, in the Eye, the *Choroides* will be ſeen diſtinctly when the Eye is under Water, tho'

no

no more Light passes thro' the *Cornea* than when it is in Air; because the Pupil is then enlarged, and allows more of that Light to pass to the Bottom of the Eye for illuminating the *Choroides*.

M. MERY seems to have been aware of this Answer; to prevent which he therefore affirms, that in the Eye of a dead Cat, the *Choroides*, which is seen under Water, cannot at all be perceived in the Air, tho' the Pupil continues equally dilated in both these *Mediums* after the Animal's Death.

§ 21. But, allowing this Experiment to be true, of which nevertheless I have some doubt, because the *French* Academists tell us, that, in the Eye of a dead Lion, which they dissected, the *Choroides* was seen of a Gold-colour thro' the *Foramen* of the *Uvea*; which makes it probable, that it may also be seen in Cats, which have so great a Conformity with the Lion in the Structure of all their Parts, both external and internal, that there appears some Ground for the Fable of the *Alcoran*, which says, that the Cat is none of GOD's Creatures, but that it was first produced in the Ark by the sneezing of the Lion. To me therefore it seems probable, that MERY's Cat has had its *Cornea* rendered opaque, by being too long exposed to the Air, and that it became more transparent, by being moistened

in

in the Water. But, I ſay, allowing this Experiment to be true, it can eaſily be accounted for, from the well known Principles of Optics, without having recourſe to the groundleſs Suppoſition, that more Light paſſes thro' the *Cornea*, when the Eye is under Water, than when it is in the Air.

For underſtanding this, Let EEF (PLATE I. *Fig.* 9.) be the Eye of a Cat in the Air, OE, OE parallel Rays falling on the *Cornea*; theſe Rays, by the Refraction of the *Cornea* and Humours of the Eye, will be made to converge to the Point F in the Bottom of the Eye; and from the Point F they will be again reflected to E, and E from thence will be refracted to O, and O in the Lines EO, EO; which Lines being parallel to one another, it may be thought that we ſhould ſee the Point F, becauſe our Eyes are ſo made as to ſee pretty diſtinctly, by means of parallel Rays; and, for the ſame Reaſon, we ought alſo to ſee all the other Points of the *Choroides*: Yet no Part of this Membrane is ſeen while the Eye continues in Air; but it is all diſtinctly ſeen, when the Eye is immerſed in Water.

But, that I may the better explain this, I ſhall next examine the Courſe of the Rays when the Eye is in Water; for which Purpoſe, let the Line WW repreſent the Surface of the Water;

Water; which being of equal Denſity with the aqueous Humour and *Cornea*, it is evident, that the Rays FE, FE, which are reflected from the Point F, will not be refracted by the Water at the Points of Incidence E, E, but will proceed in their ſtreight Courſe from E to W; but, in paſſing out of the Water into the Air at W and W, they will be refracted from the Perpendicular, and conſequently will become more diverging than before. This being the Courſe of the Rays, it follows, that the Eye, by means of thoſe diverging Rays which are now directed as if they proceeded from the Point *f*, will ſee the Point F with the greateſt Diſtinctneſs, as if placed in *f*. And the ſame Thing holds, with regard to all the other Points of the *Choroides*, which will therefore be diſtinctly ſeen, not in their proper Place, but nearer, betwixt that and the *Cornea*.

Having ſhewn the Effect of the Water in making the *Choroides* to be ſeen with great Diſtinctneſs, when the Eye is under Water, it remains that I now ſhew why this Membrane cannot be ſeen in Air by means of the parallel Rays EO, EO. The Reaſon is ſhortly this, when the *Cornea* is in Air, it acts the Part of a Mirror, becauſe it is poliſhed, and of a convex Mirror, becauſe of its Figure; it muſt therefore have its *Focus* a little behind it;

it; for convex Mirrors reflect parallel Rays, so as to make them diverge from a Point behind in the Mid-way between the *Speculum* and its Centre, as Opticians have demonstrated. And this being so, the Sun and lucid Sky, from which those parallel Rays proceed, must be seen at the Distance of Half the *Radius* behind the *Cornea*, which, by their Brightness, may hinder us from seeing any other Object beyond them, such as the *Choroides*: But, when this same *Cornea* is in Water, the small Difference that there is betwixt its Density and that of Water, makes them, in a physical Sense, homogeneous: The *Cornea* therefore is no longer a convex Mirror; it can have no more Effect on the Rays than if it were so much Water, and consequently the *Choroides* will be seen thro' it, as well as thro' so much Water; as is agreeable to Experience.

§ 22. And as M. Mery is mistaken in the Account he has given us, why the *Choroides* of a Cat is seen in Water, and not in Air; so he seems to be as much mistaken in what he says with regard to the Dilatation of the Pupil under Water.

That the Motion of the Spirits depends upon the Circulation of the Blood, and this again on Respiration, will not be denied; but neither the Motion of the Blood nor Spirits cease immediately upon the Suppression of Respiration,

but

but are observed to continue not sensibly impaired for a considerable Time thereafter; and that it is not for want of Spirits to contract the Pupil, that the Pupil is so much dilated under Water, is evident from the Struggle that the Animal makes at that very Time its Pupil is dilated; for no Animal can struggle or make any Effort whatever, without sending Spirits into the Muscles employed therein. And this shews, that, at that Time, there is no Want of Spirits for contracting the Pupil, as our Author supposes.

§ 23. The true Cause of this Dilatation seems to be twofold:

1*st*, When the Eye is under Water, there will be no Refraction of the Rays at their Incidence on the *Cornea*, and, for Want of this Refraction, they will not converge to a Point in the *Retina*, but to some other Point a great Way beyond it, and, by consequence, must take up a considerable Space upon the *Retina*, which will therefore be but weakly affected by these scattered Rays; and the *Retina* being thus weakly affected, the Pupil, which always dilates more or less, according as the Sensation of Light is weaker or stronger, must therefore be much more dilated, when the Eye is in Water, than when it is in Air. But,

2*dly*, Another Reason for this Dilatation of the Pupil, may be gathered from that Power which

which Cats are obſerved to retain over the Motions of their Pupils. In Man and moſt other Creatures, the Motion of the Pupil, however voluntary it may have been from the Beginning, is, by Uſe and Cuſtom, at laſt made neceſſary, inſomuch that it always follows the Degree of Light that ſhines upon the Eye: When the Light is ſtrong, it contracts; when it is weak, it dilates. Neither is it in our Power to do otherwiſe, becauſe we have accuſtomed ourſelves to move our Pupils in this Manner; for it is certain, that Cuſtom and Habit make many Actions neceſſary, which were not ſo originally and from the Beginning.

But, in the Cat, the Motion of the Pupil continues altogether voluntary; for, as this Creature has frequent Occaſions to be attentive to every Thing that paſſes round about it, it muſt dilate the Pupil, that the Field of Viſion may thereby be enlarged, and that the Eye may take in the more Objects at a Time; but not being able to bear much Light, that its Eyes may not be hurt by the Light, it ſhuts and opens its Pupil alternately, as we do our Eye-lids when we view an Object in too ſtrong a Light. And thus this Creature preſerves its natural and connate Liberty of opening and ſhutting its Pupil at Pleaſure, without regard to the Light that enters the Eye:

Whence it may be obſerved, that when a Cat is in a bright Light, and in an eaſy careleſs State, its Pupil is almoſt ſhut, to exclude the Light, that it may not offend the Eye. But if any Thing happens of a ſudden, that engages its Attention to what paſſes about it, it then opens its Pupil all it can, and at once, tho' there be no Change in the Light that ſhines upon the Eye. This was obſerved by the famous *Monſ. de la* HIRE (*Mem. de l' Acad. ann.* 1709.) And it may be the more depended upon, that much the ſame Thing was alſo obſerved long before, both by AQUAPENDENT and PLEMPIUS. (See AQUAPENDENT *de Oculo*, *Part.* 3. *Cap.* 6. and PLEMP. *Ophthalmog. Lib.* 1. *Cap.* 11.)

Taking it then for granted, that the Motion of the Pupil in Cats continues altogether *voluntary*, in the common Acceptation of the Word, it needs be no Wonder that this Creature ſhould dilate its Pupil greatly when under Water; for, when under Water, the Creature being very uneaſy, and in great Terror, it endeavours all it can to be attentive to every Thing that paſſes all round it, and therefore dilates its Pupil, that the Field of Viſion may be enlarged, and that its Sight may extend to as many Objects as is poſſible. And this alone ſeems ſufficient to account for the *Phænomenon* in Queſtion, tho' the Senſation of Light

Light were as ſtrong, when the Eye is in Water, as when it is in Air; the contrary of which has alſo been proved from unqueſtionable Principles.

§ 24. Having ſhewn that the Contraction and Dilatation of the Pupil depends on the Contraction and Relaxation of the circular Fibres of the *Uvea*, it may be aſked, how it comes to paſs that theſe Fibres are ſo regularly contracted and relaxed, according to the Laws above explained; for Inſtance, what determines the circular Fibres to contract for leſſening the Pupil, when the Light is ſtrong and the Object luminous; and, on the contrary, what determines them to be relaxed for opening the Pupil, when the Light is weak, and when the Object is but faintly illuminated?

That this does not proceed from the Action of the Rays upon the Fibres of the *Uvea*, or upon the Nerves belonging to them, as ſome have imagined, is, I think, very certain; for (as I have already obſerved) when one of the Eyes is affected with a Cataract, the other being ſound, the Pupil of the diſeaſed Eye does not contract ſo much as the Pupil of the ſound Eye, as may eaſily be ſeen by expoſing both Eyes alternately to the ſame Degree of Light, while, at the ſame time, the other Eye is kept ſhut. Here the Light falling upon both

the

the *Uveas*, is equal, and yet the Contraction of the Fibres is unequal: This Contraction cannot therefore be cauſed by the Action of the Light upon the *Uvea*, becauſe Effects are always proportional to the Cauſes producing them.

In like manner, in a confirmed *Gutta Serena*, or perfect Inſenſiblity of the *Retina*, theſe Fibres are not at all contracted by the Light that ſtrikes the *Uvea*; for the Pupil remains equally wide in all Lights, and is not more contracted in the brighteſt Sun-ſhine, than in the obſcureſt ſhade; which would not happen, were the Action of Light on the circular Fibres the Cauſe of their Contraction.

But, if it ſhould be alledged, that in the *Gutta Serena*, the Nerves of the *Uvea* are alſo obſtructed, and that the Immobility of the Pupil is owing to a *Paralyſis* of the muſcular Fibres of this Tunicle; to this I anſwer, That a plain Experiment ſhews the contrary. Thus, when one of the Eyes is affected with a *Gutta Serena*, while the other Eye is ſound, tho' the Pupil of the diſeaſed Eye remains immoveable and of the ſame Size in every Degree of Light, when the ſound Eye is covered or kept ſhut; yet, if the ſound Eye be expoſed to the Light, the Pupil of the diſeaſed Eye, which ſhewed no Motion before,

will

will be made to contract more or leſs, according as more or leſs Light ſhines upon the ſound Eye. This therefore plainly ſhews, that when the ſound Eye is ſhut, the Defect of Motion in the morbid one does not proceed from any *Paralyſis* of the Fibres of the *Uvea*, but only from the Want of that Cauſe, whatever it be, that determines them to contract.

I might here further add, that the Contraction of the Pupil is not only determined by the Quantity of Light that ſhines upon the Eye, but alſo by the Indiſtinctneſs of the Object, of which ſince the Light ſtriking the *Uvea* can give us no Notice or Information, it follows, that the Motions of the Pupil muſt proceed from ſome other Cauſe than the Action of the Rays upon the Fibres of the *Uvea*.

§ 25. What this Cauſe is, falls now to be explained: And, ſince we find that the Pupil is always made to contract when the Senſation of Light is ſtrong, and when the Object appears indiſtinct, to me it ſeems evident, that the Cauſe of this Contraction can lie no where but in the Mind, which being a wiſe Agent, wills the Contraction of the Pupil for intercepting a Part of the Light, and removing the uneaſy Senſation when the Light is ſtrong, and for making the Object appear more

more distinct when its Picture on the *Retina* is confused. Hence when no Light enters the Eye, or, which is the same Thing, when the *Retina* is insensible of the Light that enters it, by reason of an Obstruction or *Paralysis* of the Nerve, the Pupil is always greatly dilated; for there being then nothing that can influence the Mind to contract the Pupil, it does not then employ its active Power in willing that Motion; and therefore the Pupil must, of itself, fall into a State of Dilatation by the natural Contraction of the longitudinal Fibres, which are not *in Equilibrio* with the circular ones, till, by contracting, they have enlarged the Pupil to its greatest Size.

§ 26. Against this Doctrine several Objections may be made; such as,

*First*, If the Contraction of the Pupil depends on the Sensation that arises from the Light that strikes the *Retina*, how comes it to pass, that in Cataracts the Pupil preserves its Motions, and contracts and dilates according to the Light that shines upon the Eye, notwithstanding the Opacity of the Crystalline, which hinders the Light from being transmitted to the *Retina*?

To this I answer, That tho', in Cataracts, the Opacity of the Crystalline be such as deprives the Eye of Sight, yet it does not altogether hinder the Rays from getting to the

the *Retina*; for it is Matter of Experience, that all who have Cataracts are ſenſible of the Light when it ſhines upon the Eye, and of the Shade that is made on their Eyes when the Hand is brought before them; and they alſo all acknowledge, that their Eyes are hurt by ſtrong Light; which therefore muſt be tranſmitted to the *Retina*. Nor is it more ſtrange that they ſhould not ſee by means of of this Light, than that we ſhould not ſee the Sun when our Eyes are ſhut, by Means of the Light which paſſes thro' our Eye-lids; for when the Sun ſhines bright upon the Eyes, the Quantity of Light that paſſes thro' the Eye-lids is ſo great, as to be extremely uneaſy; and yet we ſee nothing but a confuſed Glare of Light that offends the Eye: The want of Sight in thoſe who have Cataracts is therefore no Proof that Light is not tranſmitted to the *Retina*; for the demi-opaque Cryſtalline has much the ſame Effect on the Rays, that the greeſed Paper, of which Lanterns are ſometimes made, has upon them: The Rays that paſs thro' a Lantern, made of ſuch Paper, do not make us ſee the Candle from which the Rays are emitted; but, being ſcattered every way, by the irregular Refraction of the ſecond Surface of the Paper, they come to our Eyes diverging from the ſeveral Points of that Surface, by which Means that ſecond Surface is diſtinctly ſeen, tho' the Candle

Candle itſelf be quite inviſible. In like manner, the Rays which paſs through the demi-opaque Cryſtalline are ſo ſcattered by the Refraction at its ſecond Surface, as to come to the *Retina* diverging from the ſeveral Points of that Surface; whence the external Object, from which thoſe Rays proceed, becomes inviſible, and the Cryſtalline itſelf, from the ſeveral Points of which the Rays diverge, cannot be ſeen, becauſe the Rays do not form any Picture of it upon the *Retina*, juſt as the Eye-lids are not ſeen by means of the Rays that paſs thro' them when we look towards the Sun with our Eyes ſhut: All this will be eaſily underſtood by thoſe who have any Knowledge in Optics; and therefore I ſhall not enlarge further upon it.

§ 27. Another Objection that may be made is, That, did the Motions of the Pupil depend on the Mind, we behoved to be conſcious of the Volitions or Acts of the Mind by which theſe Motions are executed.

To this I might anſwer, That there are many Motions, that unqueſtionably depend on the Volitions of the Mind, and yet theſe Volitions are not attended with any remarkable Conſciouſneſs; the Want of ſuch Conſciouſneſs is therefore no good Argument againſt the Mind's being the Cauſe of the Motions of the Pupil. But this I need not inſiſt on here,

becauſe

becauſe I think it cannot well be denied, but we are conſcious of the Volitions of the Mind on which the Motions of the Pupil depend.

But, for clearing up this Point more fully, and for explaining in what Senſe the Mind is ſaid to will the Contraction of the Pupil, it may be proper to obſerve, that the Volitions of the Mind in moving any Part of the Body, may be conſidered in the four following Views: *Firſt*, The Volition may be conſidered as reſpecting the Propulſion of the Spirits thro' certain Nerves and nervous Fibres diſcovered by Anatomiſts. *2dly*, It may be conſidered as only reſpecting the Contraction of the Muſcle itſelf that is made uſe of in that Motion. *3dly*, This Volition may be conceived to have only a reſpect to the Motion of the Part itſelf; and, *4thly*, It may be conceived, as reſpecting only the removing of an uneaſy Senſation, or the reſtoring and continuing a Senſation that is uſeful and agreeable.

Now, with regard to the Propulſion of the Spirits thro' certain Nerves and nervous Fibres, it is plain, the Mind cannot, with any Propriety of Speech, be ſaid to will this Motion; for we ſee Men who do not ſo much as know they have either Spirits or Nerves, move all their Members, and that ſometimes

with more Addreſs and Eaſe than the beſt Anatomiſts. And, for the ſame Reaſon, it can as little be ſaid, that the Mind wills the Contraction of any particular Muſcle, when it chuſes to move any Part of the Body; for none but Anatomiſts know that our Limbs are moved by Muſcles; and we ſee Children, Idiots, and Brutes, who certainly know nothing either of Anatomy or Muſcles, move their Bodies with all that Eaſe and Juſtneſs that is neceſſary.

And, with regard to our willing the Motion of the Part, this indeed ſometimes takes Place, but not always: We have an Inſtance of its taking Place in the Motions of the Hand; for when I intend to lift up my Hand, I accordingly will that Motion, and of conſequence am ſenſible and conſcious of that Volition or Act of the Mind, by which my Hand is raiſed; but I am not at all ſenſible of my having willed any Motion of the Spirits, thro' any particular Nerve or nervous Fibre, or any Contraction of any particular Muſcle. And, indeed, from what has been ſaid, it is evident, that, ſtrictly ſpeaking, I never willed any of theſe Motions; and yet nevertheleſs they both become Conſequences of that Volition or Act of the Mind whereby I willed that my Hand ſhould move.

The

The laſt Species of Willing is, that whereby we only will the removing an uneaſy Senſation, or the reſtoring and continuing a Senſation that is uſeful and agreeable; and of this Sort we have many Inſtances, of which the Motions of the Pupil is one; for it will not be denied, but when the Light is too ſtrong, we will or incline to be relieved of that uneaſy Senſation, and when the Object is indiſtinct, we will or incline to ſee it more diſtinctly: Here, ſtrictly ſpeaking, it cannot be ſaid we have willed either the Motion of the Pupil, or the Contraction of its circular Fibres, or the Motion of the Spirits thro' certain nervous Filaments terminating in thoſe Fibres; and therefore we cannot be conſcious of any ſuch Acts of Volition. All we have willed, is the removing the uneaſy Senſation when the Light is ſtrong, and the making the Object appear more diſtinct when its Picture on the *Retina* is confuſed: And this we are as much conſcious of, as we are of our willing that our Hand ſhall be raiſed when we lift it up. Nor is it more ſtrange or wonderful that the Pupil and circular Fibres of the *Uvea* ſhould contract, and that the Spirits ſhould run into theſe Fibres for contracting them, upon our willing to remove the uneaſy Senſation, or to ſee more diſtinctly, than it is that ſuch a particular Muſcle ſhould contract

contract and the Spirits ſhould flow into that Muſcle for contracting it; upon our willing to raiſe the Hand.

§ 28. What has been here ſaid with reſpect to the Motions of the Pupil may eaſily be applied to all the other Motions, the vital and natural, as well as the animal: For as in moving my Hand, and afterwards continuing it in that Situation, all I do is to will its Motion, and afterwards that it continue in the Situation I have given it, without willing the Contraction of any particular Muſcle, or the Motion of the Spirits thro' any particular Nerve; ſo, in moving the Cryſtalline, and afterwards continuing it in that Situation, all I do is to will that I may ſee the Object more diſtinctly, and afterwards that I may continue to ſee it with the ſame Diſtinctneſs, without ever thinking of the *Ligamentum Ciliare*, or the nervous Filaments that may be beſtowed upon it, of which poſſibly I may be quite ignorant. In like manner, in moving my Heart, all I do is, to will and deſire the Continuance of that Eaſe and Happineſs I enjoy while it moves right, and to remove that Uneaſineſs and Oppreſſion that attends its Reſt, and its preternatural and diſorderly Motions; for it is certain, that Children, Idiots and Brutes, move their Heart, tho' they know nothing

nothing of their being poſſeſſed of ſuch a Muſcle, or of Nerves leading to it.

I know there are many who will not allow that we will any thing at all with regard to the Motion of the Heart, and the other vital and natural Motions. And indeed it muſt be acknowledged, that theſe Motions have, by Cuſtom and Habit, become ſo very eaſy, as to be performed with very little Attention to the Volitions of the Mind from which they proceed. But it does not from thence follow, that the Mind is not concerned in theſe Motions; for we are taught by Experience that we are as little conſcious of the Volitions of the Mind, by which many Motions unqueſtionably voluntary are performed, as of the Volitions, on which the vital and natural Motions depend.

Thus, when I am ſitting in an eaſy erect Poſture, I am not only inſenſible of any Effort that is neceſſary to keep me in that Situation, but, on turning my Thoughts inwards to what paſſes in my Mind, I cannot diſcover, with any Degree of Certainty, that I am willing any thing with regard to the Situation and Poſture in which I am ſitting, and yet if I ſhall fall aſleep or be ſeized with a fainting Fit; my Head immediately falls down, and my Body deviates from its erect Poſture, which plainly ſhews, that my Continuance in that Poſture

was

was owing to the Will or active Power of the Mind, tho' I was not at the Time conscious of my willing any thing that had the least Connection with the Posture of my Body. The same Thing is also true of that Volition whereby the Eye-lids are kept open; for we are as little sensible of this, as of the Volitions by which the Motion of the Heart is continued. Many more Instances of the like Kind might be given; but more are unnecessary, as every one's Experience and Observation will easily afford him many such.

§ 29. If what has been said shall be duly considered, perhaps some Reason may be found for imagining that the Mind, properly speaking, never exerts any active Power over the Body, or, which is the same thing, that the Volitions of the Mind are not the true efficient Cause of the Motions of the Body, but only the occasional Cause of these Motions; for, since nothing can act but where it is present, the Mind cannot, with any Propriety of Speech, be said to act upon any thing that is without the *Sensorium*, or that Part of the Brain to which it is present; but, as has been already shewn, our Volitions are never directed to the *Sensorium*, or to the Spirits or any thing else that may be contained in it: All that the Mind does towards moving any Part, is to will its Motion, or the removal of some uneasy

eaſy Senſation, or the Continuance of a Senſation that is uſeful and agreeable: But ſuch Volitions as theſe, as they are not directed to any thing that is preſent with the Mind, they can have no proper Efficiency, and therefore cannot be the true Cauſe of the Motion of the Body; the occaſional Cauſe they indeed may be, and that they are, is evident from the Connection there is betwixt the Motions of the Body and the Volitions of the Mind; but ſtill there muſt be an efficient Cauſe beſides; and this can be no other, than that eternal omnipotent Cauſe on whom every thing elſe depends, or ſome ſubordinate active Intelligence, acting under him, and by his Appointment.

§ 30. But this Cauſe muſt always act at the very Time the Motion is produced. A Law eſtabliſhed from the Beginning by a *Fiat* or Decree, will not do, unleſs there be an Agent ſet apart to execute this Law or Decree; for, as it is abſolutely impoſſible that any Effect can happen *where* there is no Cauſe producing it, ſo it is no leſs impoſſible for any Effect to happen *when* there is no Cauſe producing it. This Cauſe muſt therefore operate at the Time the Effect is produced; and, to ſay otherwiſe, is to ſay ſome thing very abſurd; it is in effect to ſay, that Effects can be produced without any Cauſe at all, or, which is the

the ſame thing, that they may be cauſed by nothing, or by that which has not a Being; than which nothing can be more abſurd or ridiculous. And the ſame Thing holds true of all the Laws of Nature that do not depend upon mere Paſſiveneſs and Inactivity. Thus Gravitation, Coheſion, Attraction, *&c.* are ſaid to be Conſequences or Effects of certain general Laws; but, ſeeing Matter is utterly incapable of obeying any Laws, theſe Laws cannot continue to take place, but by ſomething ſuperior to Matter, ſome active, intelligent Cauſe, continually exerting on it a certain Force or Power, according to ſuch certain and determinate Laws.

§ 31. Mr. LEIBNITZ's famous Hypotheſis, of a pre-eſtabliſhed Harmony, as he calls it, does alſo (were it credible) very well account for all the ſpontaneous Motions of the Body, without their being cauſed by the Mind: He ſuppoſes, that the Soul does not act on the Body, nor the Body on the Soul; that both proceed by neceſſary Laws, the Soul in its Perceptions and Volitions, and the Body in its Motions, without affecting each other; but that each is to be conſidered as a ſeparate independent Machine, the Soul acting freely, according to the Laws of final Cauſes, and the Body acting mechanically, according to the Laws of efficient Cauſes; and that they only agree

agree like two Clocks, which, at the greateſt Diſtance, go alike, without at all affecting each other: So that, according to him, God, foreſeeing the Volitions and Inclinations of every Man's Soul, did from the Beginning ſo contrive and regulate the Machine of his Body, that, by the mere neceſſary Laws of Mechaniſm, ſuch Motions ſhould be excited in the Body, as might agree aud correſpond with the Volitions of the Mind.

But this Hypotheſis is altogether incredible; for how is it poſſible that ſuch Kinds of Motions, and of ſuch Variety as thoſe in the human Bodies are, ſhould be performed by mere Mechaniſm, without the Influence or Operation of any active intelligent Cauſe? Or is it credible, that, when a Man has it in his Power to reſolve and know, a Month before hand, what he will do upon ſuch a particular Day or Hour to come; is it credible, I ſay, that his Body ſhall, by the mere Power of Mechaniſm impreſſed originally upon it at its firſt Formation, punctually conform itſelf to the Reſolutions of the Man's Mind at the Time appointed? Surely, ſuch a ſtrange Hypotheſis will not be eaſily believed. But beſides, as this Hypotheſis is in itſelf incredible, ſo there is no Neceſſity of having Recourſe to it for explaining the Motions of the Body: It is now well known, and admitted by the beſt

Philoſophers, that all the Laws of Nature, that do not depend upon mere Paſſiveneſs and Inactivity, neceſſarily include in them the regular and conſtant Operation of the Deity himſelf, or of ſome ſubordinate active Intelligence, acting under him and by his Appointment. And this ſhews the Courſe and Tenor of Nature, and makes it not at all impropable, that the ſame Cauſe may take place in all the Motions of the Body, and that the Volitions of the Mind are only the occaſional Cauſe of theſe Motions. And this will be rendered ſtill more probable, if, from what is to follow, it ſhall appear, that the external Objects are not the true efficient Cauſe of the Senſations ſaid to be produced by them, but only the occaſional Cauſe of ſuch Senſations; for if Bodies do not act upon our Mind, it will not be thought ſo ſtrange that our Mind ſhould not act upon our Bodies.

§ 32. A third Objection that may be made to the Mind's having any Concern in the Motions of the Pupil, is, that, did theſe Motions depend on the Volitions of the Mind, it would then be in our Power to contract and dilate the Pupil at pleaſure, without regard to the Diſtance or Brightneſs of the Object in View. But this never happens; for, when we look at a luminous Object, the Pupil always contracts; neither is it in our Power to keep it open,

open, and, when the Object is dark and obſcure, we always dilate the Pupil, without having it in our Power to contract it; whence they conclude, that the Motion of the Pupil does not depend on the Influence of our Mind, but on ſome mechanical or other neceſſary Cauſe.

§ 33. But it is eaſy to anſwer this Objection, from what we have before obſerved with regard to the other Motions of our Eyes; to which the Reader may therefore have Recourſe: For as, at firſt, we have a Power of moving our Eyes differently, and directing them which Way we pleaſe, the one towards one Object, and the other towards another, as may be obſerved in Infants before they have diſcovered the Advantage of moving their Eyes uniformly; ſo our Mind, in like manner, does, without doubt, preſide over and regulate the Motions of the Pupil, which at firſt are alſo altogether arbitrary, like thoſe of our Eyes; for, ſince Cats are obſerved to contract and dilate their Pupils at pleaſure, without regard to the Light that ſhines on their Eyes, it is not to be doubted but at firſt we alſo are poſſeſſed of the like Power, and tho' we cannot now move our Pupils but in Conformity to the Senſation of the Light ſtriking the *Retina*, this does not make theſe Motions mechanical and independent on our Will,

Will, but only ſhews us that our Mind, which regulates and directs all our Motions to the beſt Purpoſes, has impoſed upon itſelf that law of contracting the Pupil for preſerving the *Retina*, when the Light is ſtrong, and enlarging it for making the Image more luminous when the Light is faint, becauſe of the great Advantage we receive from theſe Motions, which now by long Habit have become ſo neceſſary, that it is not in our Power to change them; it being certain that long Cuſtom and Habit do render many Actions in a Senſe neceſſary, which were not in themſelves eſſentially ſo, nor from the Beginning.

It is unneceſſary here to repeat the many Inſtances we have formerly given of this; the uniform Motions of our Eyes alone is ſufficient to eſtabliſh this Doctrine; for it cannot be denied, that the Motions of our Eyes are all voluntary, and depending on our Mind; and that at firſt we have a Power of moving them differently, and directing them to different Objects at pleaſure; yet, at laſt, long Cuſtom makes that uniform Motion in a manner neceſſary, inſomuch that we are now no longer at Liberty to move them differently: When the Right-eye, for Inſtance, is turned to any Object, the left one follows its Motion, and is directed to the ſame Object: Neither is it in our Power to direct it to any other; not

not becauſe its Motions do not depend on the Volitions of the Mind, or that the Mind is under any phyſical Neceſſity of making it follow the Motion of the other, but merely becauſe we have been in the Uſe of moving them uniformly, from which a Neceſſity of a different Kind has grown up, that we cannot now ſo eaſily get the better of.

Now, as the Motion of the one Eye always follows the Motion of the other, not from any abſolute or mechanical Neceſſity in the Thing itſelf, but only becauſe we have been in Uſe of moving them together; ſo the Motions of our Pupils do in like manner follow the Senſation of the Light that ſtrikes the *Retina*, merely becauſe we have been accuſtomed to move them in that Manner; and the one is no more neceſſary, mechanical, involuntary, or leſs under the Goverment and Direction of the Mind, than the other.

§ 34. And what I have ſaid with reſpect to the Motions of the Pupil, holds equally with reſpect to all the vital and natural Motions; for, in the Beginning of Life, theſe Motions ſeem to have been altogether *voluntary*, in the common Acceptation of the Word; and tho', by Cuſtom and Habit, they have at length become ſo neceſſary, as to make it impoſſible for us to hinder them from going on in their uſual Manner; yet this

this does not make them independent on the Volitions of the Mind; ſince the uniform Motion of our Eyes, and the Motions of the Pupil, are without doubt cauſed by the Mind, tho', at the ſame time, they ſeem as neceſſary and as much independent on the Volitions of the Mind, as are any either of the vital or natural Motions.

§ 35. For illuſtrating and confirming this, it may be of Uſe here to remark, that the Power of the Mind over the Motions of the Body, is not only different in different Parts of the Body, and in different Stages of Life; but in the ſame Parts of the Body, and at the ſame time of Life, this Power is alſo different in different Animals.

I have already obſerved, that the Motions of our Eyes, whereby they are directed to Objects, are at firſt unqueſtionably *voluntary*, in the common Acceptation of the Word; and yet in time, by Uſe and Habit, they become in a Manner neceſſary, inſomuch that we cannot now give them different Directions; whereas the Hare, Coney, Cameleon, and divers other Creatures, preſerve their natural and connate Liberty of moving them differently.

The Motions of the Pupils in Cats are likewiſe altogether voluntary; whence it is reaſonable to believe, that theſe Motions in Man

Man were at first also voluntary, and yet, by Custom and Habit, the Mind seems now to have lost its Power over them, and cannot move them but in Conformity to the Light affecting the *Retina;* but Cats still preserve their original Liberty, and are observed to contract and dilate their Pupils at Pleasure, without regard to the Light that shines on the Eye. And what I have said of Cats, I imagine, holds also true with respect to Birds: For Dr. MONRO *Junior*, from whose Skill and Diligence in Anatomical Matters we have Reason to expect many useful Improvements in this fundamental Branch of Medicine, assures me, that he has frequently observed this voluntary Motion in Parrots, who, while the Light that shines on their Eyes continues the same, may be observed to contract and dilate their Pupils at pleasure, without regard to the Light that acts on the Eye.

The Motions of Respiration are also, I think, altogether *voluntary*, in the common Use of the Word; and I make no doubt, but, in the Beginning of Life, they required a direct and manifest Exertion of the Mind's active Power, as well as the other voluntary Motions; and yet now, by Use and Custom, these Motions have become in a Manner necessary, so as to go on regularly as of themselves, without any seeming Interposition of the Mind, and

that

that as well when we are asleep, as when waking, tho' the Mind, in all Animals I know, still preserves its Power over them, and can accelerate, retard, and put a stop to these Motions at pleasure.

The Motions of our Heart, in the Beginning of Life, seem also to have been altogether *voluntary*, in the common Acceptation of the Word; but, by Use and Custom, they have become necessary, so as we cannot now vary or put a stop to them; and yet, which is very remarkable, Dr. LISTER, in speaking of the *Cochlea*, in his Book *de Cochleis et Limacibus p.* 38. assures us, "That, in this Animal, the Motion of its Heart is so very irregular, sometimes beating quickly and violently, sometimes not beating at all, for the Space of a full Quarter of an Hour, that there can be no doubt, but that in this Species of Animals, the Motion of the Heart is voluntary, and not merely natural, as in Man, and other sanguinious Animals; but that it can be moved or stopped for a longer or shorter Space of Time, as the Creature pleases." Whence it seems evident, that this Animal retains its natural Power and Liberty over the Motion of its Heart, as the Cat does over the Motions of its Pupil, as the Hare, Coney, and Cameleon, do over the Motions of

the

the Eye, and as these and all other Creatures do over the Motions of Respiration.

I might here again mention the Case of Colonel TOWNSHEND, who, as Dr. CHEYNE on the *English Malady*, (*p.* 307.), tells us, could, at pleasure, suppress all the vital Motions, so as in all respects to appear dead; and yet, by an Effort, or some how, he could come to life again, and restore these Motions. The Case is indeed singular, but not at all to be accounted for, without allowing the Mind to preside over, and by its Volitions to regulate and direct the vital as well as the other Motions.

§ 36. But, that what I have said on this Subject may not be mistaken, it may be proper here to observe, that tho' vulgarly, in a loose, figurative and improper Speech, we say, that the Motion of the Pupil, the uniform Motions of our Eyes, the vital and natural Motions, are necessary, involuntary, not under the Power and Dominion of our Will; yet, in truth, and in Strictness of speaking, as they are all caused by the Volitions of the Mind, they must necessarily be both voluntary and free, and of consequence intirely subject to the Power and Influence of this active Principle; for I think a necessary Agent, or necessary Action, is a Contradiction in Terms; for whatever acts necessarily, does not indeed act at all, but is

only acted upon; is not at all an Agent, but a mere Patient; does not move, but is moved only. All Power of acting, essentially implies at the same time a Power of not acting; otherwise it is not acting, but barely a being acted upon by that Power, whatever it be, which causes the *Action*; and if a Power of acting implies a Power of not acting, acting cannot be necessary: The Mind therefore must be free in the Exercise of its active Power, and in the Volitions whereby the vital and natural, as well as the other Motions, are produced; nor does is make any Difference in the Case, whether these Volitions are supposed to be the efficient or only the occasional Cause of these Motions.

§ 37. When we therefore say, that the vital and natural Motions are necessary, and that it is impossible for us to vary or stop them, this is indeed true; but the Necessity and Impossibility here spoken of can only be a moral Necessity, and a moral Impossibility, which, in truth and philosophical Strictness of Speech, is indeed no Necessity or Impossibility at all, but only a figurative Manner of speaking, which, like all other figurative Expressions, has nothing at all of physical Reality in it, but leaves the Mind at absolute Liberty to do as it pleases. I shall illustrate this in an Example.

We

We ſay, it is impoſſible, and a Contradiction in Terms, morally ſpeaking, that a wiſe Man, continuing to be wiſe, ſhould do a fooliſh Thing, or an honeſt Man, continuing to be honeſt, ſhould do a diſhoneſt Thing, or a veracious Perſon, continuing to be veracious, ſhould tell a Lye. But it is no Contradiction in Phyſics; the Man is at abſolute Liberty to do as he pleaſes, but does not chuſe, and indeed, morally ſpeaking, cannot chuſe to act in Contradiction to his fixt and determined Reſolution of acting always agreeably to what he ſees to be fit and right.

From this Inſtance we may ſee, how in like Manner the Mind, after having impoſed upon itſelf a Law, whereby it regulates and governs the vital and natural Motions to the greateſt Advantage, it cannot now poſſibly act but in Conformity to this Law, by reaſon of the Utility and Advantage that ariſes from this Way of acting, in which it has been fixed and confirmed by a long continued Habit and Cuſtom; and yet its acting ſo, is not becauſe it wants a natural or phyſical Power to act otherwiſe; but becauſe it is abſurd, miſchievous, and morally impoſſible for it to chuſe to act ſo fooliſhly and unreaſonably, and ſo much contrary to that Neceſſity that has been fixed and eſtabliſhed by Habit and Cuſtom.

§ 38.

§ 38. But you will say, that tho' the Mind should be allowed to regulate and direct the Motions of the Heart, and the other vital and natural Motions, while the Animal is awake, how is it possible it should continue to will these Motions, and that so regularly and orderly in time of Sleep, when the Mind may be supposed to be in a State of Insensibility, Torpor or Deadness, being both inactive and impercipient?

To this I answer, That, in time of Sleep, the Mind is neither inactive nor impercipient; and their is good Reason to believe, notwithstanding what the great Mr. LOCKE says to the contrary, that the Mind always thinks, is always sensible and active, and of consequence is always conscious as well sleeping as waking. This much at least is certain, that Experience can never prove the contrary. Who can say that he ever found himself in a State of Unconsciousness, or when there was no Idea at all subsisting in his Mind? Indeed, it is contradictory that any Man should so surprize himself, impercipient, to wit, of all Things with respect to the *present Time*: For he is conscious by Supposition, and reflecting upon an unconscious State; which is a Contradiction in Terms.

And,

And, as to the *paſt Time*, he cannot have any Memory of ſuch a State; for whether ever ſuch a State *was* or *was not*, it is either way a Contradiction that he ſhould remember it; and he cannot bring an Argument for it from his not remembering of it. If a Man came through a dark Room, he may be certain there was no Light there; for his Eyes were open, and he miſſed the Light: But if a Man paſſed an Hour of inconſcious Exiſtence laſt Night, there is a wide Difference; he did not perceive an Abſence of Conſciouſneſs then, nor can he now, ſince he could not do it but by remembering it: He hath not two diſtinct Conſciouſneſſes, one to be extinguiſhed, and another remaining to perceive the Abſence of the firſt: He doth not perceive at the Time, and therefore cannot recollect afterward the laſt Thought he was conſcious of, at the Beginning of the Blank, nor the firſt upon emerging out of it (to be the two Extremes, as it were), nor the Diſtance and Length of Time betwixt; he muſt therefore think thoſe two Extremes continguous, and thence conclude that he had been conſcious without Intermiſſion.

It is therefore ſomewhat ſtrange to appeal to Experience for the Reality of a State, which, by Suppoſition, is an utter Negation of all Experience. Mr. LOCKE ſays, "the

" the Queſtion is about a Matter of Fact;" but to this I reply, the Queſtion is about a Matter of *not Fact;* about a Negation of all Fact. Every body allows we are generally conſcious; this is not the Queſtion then: But if we are ſometimes without Conſciouſneſs, it is abſurd to ſay, we forget our Unconſciouſneſs; it is abſurd to ſay, we remember our Unconſciouſneſs. Where is the Matter of Fact to be teſtified to them? Or how is Experience applicable?

And as we can have no Proof from Experience that the Mind is ever inſenſible or inactive, ſo, on the other Hand, there are many Arguments that might be brought to prove, that Animals are always both percipient and active, and that as well when aſleep as waking. But that I may not weary the Reader with metaphyſical Reaſoning, I ſhall here only obſerve, that Horſes, Cows, and ſeveral other Quadrupeds, are ſometimes obſerved to ſleep ſtanding, ſome Men ſleep riding on Horſeback, others in time of ſleep get out of Bed, and after wandering thro' the Houſe, go to Bed again, without remembering any thing of it next Morning: Many Fowls ſleep with their Heads turned under their Wing, and ſome alſo are obſerved to ſleep ſtanding upon one Leg, having the other drawn up to their Belly. Theſe Inſtances are ſufficient to ſhew

that

that Animals are both percipient and active in time of ſleep; for all theſe *Phænomena* neceſſarily imply both Perception and Action, without which they could not take place. Whence I conclude, that an Animal's being aſleep needs be no Hindrance to its exerting its active Power, in regulating and conducting the vital and natural Motions with all that Order and Regularity we obſerve.

The famous BORELLI, finding that many Fowls ſleep ſtanding on ſmall Branches of Trees, even when they are agitated by the Winds, has endeavoured to account for this *Phænomenon* from mechanical Principles (ſee his curious and truly beautiful Treatiſe *de Motu Animalium*, *p.* 1. *Prop.* cl.). And indeed, it muſt be owned, that the mechanical Diſpoſition of the Muſcles which bend their Toes, by reaſon of the Weight of their Body, bending all the Joints of their Thighs, Legs and Feet, over which the Tendons of theſe Muſcles paſs, muſt be of ſome Service in making them grip the Branch more forcibly, and by that Means may in ſome Meaſure contribute towards keeping them from falling, in the Manner BORELLI has explained; yet I think it extremely obvious to any one who ſhall conſider the Matter with any Degree of Attention, that this Mechaniſm alone is altogether inſufficient for producing the Effect in Queſtion;

Queſtion; and that there muſt needs alſo be a conſtant Exertion of the active Power of the Mind, without which they behoved to tumble down, eſpecially when the Branch is agitated by the Winds.

§ 39. Before I diſmiſs this Subject, it may be expected I ſhould take ſome notice of what Dr. WHYTT has advanced on the *vital* and *natural Motions*.

This ingenious Gentleman, in the Advertiſement to his Book on the *vital Motions*, tells us, That, about the Year 1739, not long after he he had left the Schools of Medicine, he began to be diſſatisfied with the common Theories of Reſpiration and the Heart's Motion; and as he had not met with any Writer, who had given (as he thought) a juſt Account of the vital and other involuntary Motions of Animals, or derived them *rightly* from their true Source, he propoſed ſome Time or other to write on this Subject: In purſuance of this Reſolution, he began his Eſſay in the Year 1744; which he finiſhed and publiſhed *anno* 1751. In compiling this Eſſay, he tells us, he has been careful not to indulge his Fancy, in wantonly framing Hypotheſes; but has rather endeavoured to proceed upon the ſurer Foundations of Experiment and Obſervation. The Reſult of all which is, that he ſo far agrees with me, in what I had publiſhed about 16 Years before that,

that, in the *Medical Eſſays* of *Edinburgh*, as to maintain, that all the vital and natural Motions depend on the Mind; ſometimes he ſays, on the *Exertion of its Power and Influence*, p. 300. and 301. on *the Energy and active Power of the Mind*, p. 302. and 324. on *the Energy of a living Principle capable of generating Motion*, &c. p. 271.

But he differs from me in making them *altogether involuntary*, p. 311. *abſolutely involuntary*, p. 309. *not ſubjected to the Will*, p. 307. *wholly neceſſary*, p. 311. *ſtrictly neceſſary*, p. 308. *neceſſary and independent on the Will*, p. 315.; and ſays, that the Mind, in performing theſe Motions, *has no Views*, p. 285. and 308. *propoſes no End*, p. 288. and 308. *acts without Choice*, p. 307. and 308. *without Preference or Election*, p. 286. *is a neceſſary Agent, even in the very ſtrongeſt Senſe of the Word*, p. 306.; being *as neceſſarily determined by a* Stimulus *affecting the Organs to exert its Power in bringing about theſe Motions, as is a Balance, while, from the mechanical Laws, it preponderates to that Side where the greateſt Weight prevails*, p. 289. or, *as is a Stone in falling to the Ground*, p. 308.: And he further ſays, That the Mind's being thus neceſſarily determined by *Stimuli, is owing to the original Conſtitution of our Frame, and the Law of Union eſtabliſhed by the Allwiſe Creator between the*

*Soul and the Body, whereby the former immediately, and without any Exercise of Reason, endeavours by all Means, and in the most effectual Manner, to avoid and get rid of every disagreeable Sensation conveyed to it, by whatever hurts and annoys the Body*, p. 309.

§ 40. But not to insist on the Impropriety of saying that the vital and natural Motions proceed from the *Energy and active Power of the Mind*, from the *Energy of a living Principle, capable of generating Motion*, while, at the same time, his real Opinion is, That they are not at all *caused by the Mind*, but are *strictly necessary*, in the strongest Sense of the Word, and *caused by a Law* established by the All-wise Creator: I say, not to insist on this, I shall here only observe, that this Hypothesis, (for a Hypothesis I must call it, till it receives some further Proof), I say, this Hypothesis, as I see no solid Argument supporting it; so to me it seems much more incredible than the Hypothesis of the learned Dr. HALLER, which he labours so much to refute.

Dr. HALLER's Opinion is, "That Irritability, or the Contraction arising from the "Application of *Stimuli*, is a particular Property of muscular Fibres, in like Manner "as Gravity is a Property of Matter; and that "it does not depend on the Nerves, and has "no Connection with Sensibility." So that, according

according to this learned Gentleman, the Motions arising from Irritation are altogether similar to those arising from Gravity, both being strictly necessary, and caused by a Law, or rather by GOD himself, or some active intelligent Being acting under him, and by his Appointment executing that Law: And in this Dr. WHYTT entirely agrees with Dr. HALLER.

But they differ in this, That Dr. HALLER makes this Law, or rather the Power that executes it, to act immediately upon the Fibres themselves, in consequence of the Application of the *Stimulus*; which Application of the *Stimulus* is therefore to be considered as the occasional Cause of the Motion, just as the relative Situation of Bodies with respect to the Earth, is the occasional Cause of their Gravitation and Descent. Whereas Dr. WHYTT does not allow this Law, or the Power that executes it, to act immediately on the Fibres for contracting them, but to act immediately on the Mind, and, by acting thus on the Mind, to necessitate it, by an absolute physical Necessity, to contract the Fibres: So that, according to him, the Mind is only a passive Instrument in the Hand of that active intelligent Cause that executes the Motion of the Fibres. And with respect to the occasional Cause of this Action, Dr. WHYTT, in place of

of making it consist in the simple Application of the *Stimulus* to the Part stimulated, as Dr. HALLER supposes, thinks there must also be a subsequent Sensation, without which the active intelligent Being moving the Fibres does not act, tho' this Sensation seems to be intirely unnecessary, as the Mind, according to him, has no active Hand in these Motions, is strictly necessary, has no Views, proposes no End, acts (if it may be said to act at all) without Choice, without Preference or Election.

But this Hypothesis of Dr. WHYTT, to me, seems extremely improbable, nor can it, in my Opinion, be well maintained, without trespassing against the Rules of Philosophizing that have been admitted by all sound Philosophers. Sir ISAAC NEWTON, and other Philosophers, both before and after him, tell us, That Nature does nothing in vain, is very simple and uniform, and delights not in things superfluous or unnecessary. On this Principle Sir ISAAC founds the whole 3d Book of his *Principia;* and I know no sound Philosopher that ever contraverted it. And this being so, it may reasonably be asked, For what End must the Mind be informed by a Sensation of the Application of the *Stimulus* to the Part stimulated? Did the Motion of the Part any way depend on the Volitions of the Mind, there

there would be ſome Reaſon for this Information: But as this is not the Caſe; as the Mind is not allowed to have any Choice, any Volition, nor to be any way ſubſervient to the Contraction of the Part, but only as a paſſive Inſtrument made uſe of by that active intelligent Cauſe, by which the Part is moved, this Senſation ſeems to be intirely unneceſſary and ſuperfluous, anſwering no wiſe End or Purpoſe; and therefore cannot be ſuppoſed to have been ordained by the Allwiſe Author of Nature.

In like manner, it may be aſked, Why this active intelligent Cauſe does not apply its active Power immediately to the Part itſelf, without the Interpoſition of the Mind? It will not, I believe, be ſaid, that this active Cauſe could not, of itſelf, and without making uſe of the Mind, or any other Inſtrument, have as eaſily affected this Motion, by acting immediately on the Part itſelf: And this being ſo, it is not to be imagined, that this unneceſſary round-about Way would have been appointed by the Author of all Things, who does nothing in vain, nothing ſuperfluous, or without Cauſe.

The learned Dr. HALLER's Hypotheſis is not liable to theſe Objections, and therefore ſeems much more reaſonable. From it alſo,

it

it is eaſy to account for the Motion of the Heart and the other muſcular Parts of Animals after Death, and their Separation from the Body, and for the renewing of theſe Motions after they have ceaſed, by the Application of *Stimuli*. And this is another Argument in favours of this Hypotheſis. Dr. WHYTT, it is true, has alſo endeavoured to account for theſe Motions from his Hypotheſis. But in this I think he has failed; nor do I believe that what he has ſaid on that Head can give Satisfaction to any body, as has been ſhown above at ſome Length.

§ 41. But, tho' Dr. HALLER's Hypotheſis ſeems more reaſonable than that of Dr. WHYTT, yet for all that, I do not think, that it can reaſonably be admitted, without ſome further Proof. The great Argument for this Hypotheſis is, That without it the Motions of the Heart, and the other muſcular Parts after Death, and their Separation from the Body, ariſing from the Application of *Stimuli*, appear inexplicable, if not altogether impoſſible. But to this I Anſwer, That theſe Motions are neither inexplicable nor impoſſible; for tho' it has been demonſtrated, that a perpetual *Mobile* is a thing impoſſible, and repugnant to the Laws of Mechaniſm, and conſequently that the vital and natural Motions cannot go on perpetually by Mechaniſm alone,

alone, without the powerful Influence and Operation of the Mind, or ſome other active immaterial Cauſe, capable of generating Motion; yet there is nothing to hinder ſuch tranſient and ſhort-lived Motions, as thoſe excited by *Stimuli* applied to the Parts, from being cauſed by the mechanical Action of the *Stimulus*; and tho' we cannot fully explain the Mechaniſm of muſcular Fibres, and thence ſhew particularly how theſe Motions are cauſed by the *Stimulus*, it is enough, that, in general, we can, with truth, affirm, that ſuch Motions are poſſible, and may be truly mechanical. And it is incumbent on Dr. HALLER to prove that they cannot poſſibly proceed from Mechaniſm, before he can expect that we ſhould admit of this new Law invented by him for explaining theſe Motions. But I have dwelt too long on this Subject, and muſt now return.

§ 42. From what has been ſaid on the Motion of the Pupil, we may ſee the Reaſon why our Pupils come to ſympathize with each other in their Motions; for having been accuſtomed to move them ſimilarly, becauſe of the Benefit that ariſes to us from that kind of Motion; we come at laſt to be no longer able to move them differently, juſt as we cannot now direct the one Eye to any Object without turning the other the ſame Way.

We

We may from this alſo ſee whence it is that in thoſe who, from a Cataract or *Gutta Serena*, have been blind from their Birth in any one of their Eyes, this Sympathy betwixt the Pupils does not take place; for as ſuch Perſons could never reap any Benefit from moving their Pupils in the ſame Manner, the Mind did not accuſtom itſelf to that Sort of Motion, and of conſequence muſt preſerve its natural and connate Liberty of moving them differently.

From this alſo we may ſee, how this Sympathy may be again loſt, even after it has in ſome meaſure been eſtabliſhed by Habit and Cuſtom; for if one Eye be loſt before this Sympathy has been fully fixed and eſtabliſhed by a long continued Habit, the Mind, finding no further Advantage in moving the Pupils the ſame Way, may gradually forget and loſe the Habit it had acquired of moving them in that Manner, and at laſt may come to move them differently; we are not therefore to be ſurpriſed, if we ſhould ſometimes find, that, when one of the Eyes has for a good while been loſt by a *Gutta Serena*, the Pupil of the diſeaſed Eye continues quite immoveable without following the Motions of the other. I do not indeed remember any Author that has given us an Inſtance of this; and I have not myſelf been careful enough to obſerve it; yet that

that it may ſometimes happen, ſeems evident from the Analogy there is betwixt the ſimilar Motions of our Pupils, and the uniform Motions of our Eyes; they are both founded on Cuſtom and Habit, and on nothing elſe; and therefore, if the Mind can get the better of that Neceſſity whereby our Eyes move uniformly, it may alſo get the better of that Neceſſity whereby our Pupils move ſimilarly; and that we get the better of that Neceſſity by which our Eyes move uniformly, is evident from the diſſimilar Motions of the Eyes, that are ſo frequently obſerved in blind People, and particularly from that remarkable Hiſtory recorded by PLEMPIUS, of a Girl who became blind from a *Gutta Serena* in the 5th Year of her Age. This Girl, finding no further Advantage, after being blind, in moving her Eyes the ſame Way, came at laſt to forget the Habit ſhe had formerly acquired in the four Years ſhe ſaw, and moved her Eyes differently; ſometimes their *Axes* being parallel, ſometimes converging, and at other times diverging. (See PLEMPIUS *Ophthalmograph. lib.* 4. *Problem* 13.) I had Occaſion to mention this Hiſtory before; but, as it ſerves to prove the Point now before us, the Reader will forgive me for mentioning it again in this Place.

These Things being considered, it is evident, that the Age of a *Gutta Serena* may sometimes be better determined from Theory than from Information. Thus, if any Person having a *Gutta Serena* in one of his Eyes shall tell me, that he lost the Sight of it only a Month ago; yet if I find that the Motion of its Pupil does not follow the Motion of the other Pupil, and that the Eyes themselves do not move uniformly, I thence conclude that this Eye was blind from the Birth, or not long after it, tho' the Person himself did not discover it, because he had not attempted to see any Object with the diseased Eye alone, while the other was shut; and being thus certain, that he was blind of this Eye from the Birth, or soon after it, I can with Confidence assure him, that all Attempts towards a Cure will be fruitless and to no Purpose.

How we come to judge of the Age of this Disease from the Mistakes they commit in pouring Liquor into a Glass, snuffing a Candle, threading a Needle, and such other Actions as require that the Distance be exactly distinguished, shall be explained afterwards in its proper Place, to which the Reader may have Recourse.

§ 43. Having thus explained the Motions of the Pupil, and the Causes on which they depend, it remains, that I now inquire into the

the Advantages we receive from theſe Motions. But as moſt of theſe Advantages may be eaſily gathered from what has been already ſaid, I need but juſt mention them, without enlarging at all upon them.

§ 44. GALEN, and all thoſe who, from his Authority, thought that the Pupil had no Motion, but that of dilating itſelf when one of the Eyes was ſhut or loſt, and again contracting itſelf when the Eye was opened or recovered, were of Opinion, that the only Uſe of its Motions was, to enable us to ſee more clearly, and by that Means to ſupply the Want of the ſhut or loſt Eye. But ſince this Hypotheſis is founded upon an Error in Fact, we need not waſte Time in examining it.

§ 45. The famous *M. de la* HIRE maintains, that the great Uſe of the Mobility of the Pupil is, to enable the Eye to ſee diſtinctly at different Diſtances, without being obliged to change its Conformation, which, according to him, never happens; for, after having endeavoured to prove, by ſeveral ingenious Arguments, and particularly by the Experiment formerly mentioned, of looking to a ſmall Object thro' two Holes made in a Card, in which the Object always appears double, excepting when it is at ſome one determined Diſtance ſuited to the Eye of the Obſerver,

Obſerver. I ſay, after endeavouring to prove that the Eye does not change its Conformation, his next Attempt is to ſhew, that there is no need of any ſuch Change, and that, by means of the Contraction of the Pupil alone, we may ſee at different Diſtances diſtinctly enough, ſo as not to be ſenſible of any Confuſion, tho' the Conformation of the Eye continue invariably the ſame. The Arguments he brings againſt any Change of Conformation in the Eye have already been all fully anſwered, and a Proof of this Change has been brought from unexceptionable Experiments; ſo that it now only remains, that I ſhew the Inſufficiency of the Motions of the Pupil, to procure diſtinct Viſion at different Diſtances.

That the Contraction of the Pupil does diminiſh the Indiſtinctneſs of the Picture on the *Retina*, and conſequently that of the Object, by contracting the Pencils of Rays that flow in at the Pupil from each Point of the Object, is undeniable; but ſince this Contraction depends more upon the Strength of Light, than upon the Senſation of Confuſion in the Object, tho' ſometimes it may contribute to make the Object more diſtinct, at other times it muſt have a quite contrary Effect, and make it appear more confuſed; for if a luminous Object, ſuch as a bright Flambeau, be placed

placed at six Feet Distance, and another Object of a black, brown, or other obscure Colour, be placed at a Foot Distance, this luminous Object, notwithstanding its greater Distance, will emit more Light into the Eye than the other; and consequently, when viewed, will cause the Pupil to contract more; and therefore the little Cones of Light, which have their *Basis* in the Pupil and their *Apex* in the several Points of the Object, will be much more acute in the distant Flambeau than in the other dark Body: Whence it follows, that if the Conformation of the Eye be such as is necessary for seeing the Flambeau distinctly, the other Object at a Foot Distance must appear confused, unless the Eye change its Conformation, and adapt itself to the more obtuse Cones of Rays that come therefrom; for these Cones are not only obtuse, by reason of the Proximity of the Object, but are rendered still more obtuse, by the Dilatation of the Pupil; from which it is evident, that if the Eye were deprived of a Power of changing its Conformation, and adapting itself to the Distances of Objects, Objects, in place of being rendered more distinct, would sometimes be made more confused by the Motions of the Pupil; and therefore it must be allowed, that the Faculty of seeing distinctly at different Distances, is not to be ascribed to the Mobility of

of the Pupil, as *de la* HIRE ſuppoſes, but to the Motion of the Cryſtalline; as has been above explained.

§ 46. It remains therefore, that the Mobility of the Pupil muſt have ſome other Uſe than theſe juſt now mentioned from GALEN and *de la* HIRE, which now falls to be noticed.

1*ſt*, Then it dilates when the Light is weak, that a greater Number of Rays may enter the Eye, from each Point of the Object, which being united in ſo many correſponding Points in the *Retina*, will make the Picture more bright and lively; and conſequently render Viſion more clear and ſtrong than it could have been, had the Pupil continued invariably the ſame.

2*dly*, It contracts when the Light is too ſtrong, and the Object too bright or luminous for intercepting a Part of the Light, which otherwiſe would have hurt or deſtroyed the tender Subſtance of the *Retina*, by its too great Strength and Activity.

3*dly*, Beſides the Advantage we receive from the Mobility of the Pupil, in proportioning the Quantity of Light which enters the Eye to the Senſibility and Delicacy of the *Retina*, there is yet another taken notice of by ſome of our optical Writers, which conſiſts in enabling us to judge with greater Certainty of the Diſtance of Objects; for it cannot be denied, that

that the apparent Colours of Bodies are very uſeful for us in judging of their Diſtances, as often as we are otherwiſe well acquainted with the Intenſity and Vigour of their Colour at any other determined Diſtance; and therefore, though the Pupil ſhould, by its Contraction, allow no more Light to paſs to the *Retina* when the Object is near, than when it is further off, yet, when it is near, we muſt be ſenſible of the Intenſeneſs of its Light, becauſe we know, that the Pupil is then contracted; for, ſince the Motions of the Pupil depend on the Volitions of the Mind, the Mind muſt always be more or leſs ſenſible of its Motions: And beſides, when the Pupil is contracted, we ſee more diſtinctly than when it is dilated, by which alſo we are ſometimes aſſiſted in judging of the Diſtances of Objects: But this will be explained more fully afterwards, when we come to treat of the *Phænomena* of Viſion.

§ 47. From what has been ſaid, it will be eaſy to anſwer the following Queries:

## QUERY I.

*Why do we ſee moſt clearly when the Pupil is dilated.?*

To this I anſwer, That, when the Pupil is dilated, a greater Quantity of Light enters the Eye,

Eye, which, after Refraction, muſt paint upon the *Retina* a more clear and lively Image of the Object, and agitate the Fibrils of the optic Nerve with more Strength and Briſkneſs, and therefore muſt impreſs the Mind with a ſtronger and more lively Senſe of the Object. And from this appears the Reaſon, why the Owl, Bat-bird, and other Night-birds cannot bear the Light of Day; for their Pupils being exceeding large, when Objects are illuminated with Day-light, they appear ſo very clear and bright, from the Multitude of Rays which enter their dilated Pupils, that their delicate *Retina* is not able to bear the Force and Vigour of the Image. And the ſame Thing ſometimes happens to ourſelves; for when we have been for ſome Time in a dark Place, and then go into another ſtrongly illuminated, our Eyes are hurt by the Quantity of Light that paſſes through our dilated Pupils; for our Pupils always enlarge in Darkneſs, and require ſome Time to contract ſo as to enable us to bear a ſtrong Light.

## QUERY II.

§ 48. *Why does the Eye ſee moſt diſtinctly when the Pupil is contracted?*

I anſwer, *firſt*, When the Pupil is contracted, the luminous Pencils which flow to the Pupil

Pupil from the ſeveral Points of the Object, will be made narrower and leſs diverging, and therefore, tho' the Rays belonging to theſe Pencils ſhould not be accurately united in a Point on the *Retina*, yet they will take up but a ſmall Space upon it; ſtill the ſmaller the more the Pupil is contracted; by which means the Confuſion in the Picture will become leſs, and the Sight will be made more diſtinct, tho' leſs clear. But,

2*dly*, When the Pupil is large, the Eye will not be a *Cellula Obſcura*, but will be enlightened by the Light reflected from Objects placed all round that towards which the Eye is directed; and being thus enlighted, the Picture on the *Retina*, by being mixed with this foreign Light, will be rendered obſcure and indiſtinct, and conſequently the Viſion produced by this obſcure indiſtinct Picture will alſo be obſcure and indiſtinct; for the *Retina* being agitated both by the Rays which come from the Object in view, and by the other adventitious Rays that belong to other Objects, the Senſe of Light will indeed be augmented, but the Mind will not be able to diſtinguiſh the Object in view with that Diſtinctneſs it would otherwiſe do.

This may be illuſtrated by a *Camera Obſcura*; for, as in ſuch a *Camera* the Pictures are al-

ways the moſt lively and perfect when the *Camera* is kept quite dark, and no Light is allowed to enter but what comes from the Object forming the Picture; ſo, in the Eye, the Pictures will always be the moſt lively and perfect, when, by the Contraction of the Pupil, no Light enters the Eye to mix with the Picture but what comes from the Object in view, and conſequently the Sight produced by ſuch Pictures will then alſo be moſt diſtinct and perfect.

§ 49. Many of the antient Phyſicians affirm, that, when the Pupil is dilated, as in the *Mydriaſis*, Objects appear ſmaller; and, on the contrary, when it is contracted, as in the *Myoſis*, or *Phthiſis Pupillæ*, that they appear larger. PAULUS ÆGINETA is the firſt I know that publiſhed this Doctrine; from whom he had it, I know not, nor does he any where inform us. From GALEN he had it not; for this learned *Greek* makes not the leaſt mention of it in any of his Writings. If he was led to it by his own Reaſon and Philoſophy, he is certainly much deceived; for it neither agrees with Reaſon nor Experience. AETIUS alſo teaches the ſame Thing, without telling his Author; and afterwards it came to be pretty much the Doctrine of the Schools of Medicine; few Phyſicians venturing to

to contradict what had been affirmed by those who went before them. But it is doing Penance to read the wretched Stuff they have thrown out in endeavouring to account for it.

That the Magnitude of the Pupil has no Influence on the Magnitude of the Object, must be evident to every Body that reflects on the Manner of Vision; for Vision, in so far as our Eyes are concerned, consists in nothing but such a Refraction of the Rays of Light, by the transparent Skins and Humours of the Eye, as is necessary to unite and bring together the Rays which come from the several Points of the Object, in so many corresponding Points in the Bottom of the Eye, and there to paint the Picture of the Object upon the *Tunica Retina*, with which the Bottom of the Eye is covered; but the Rays of each Pencil being always united in the *Axis* of the Pencil, they will fall on the same Point of the *Retina*, whether the Pupil be contracted or dilated; and consequently the Magnitude of the Picture will be the same in both Cases, and, being the same, the Object must also be seen of the same Magnitude. This may be illustrated by the vulgar Experiment of casting the Species of Objects from abroad upon a Wall or Sheet of white Paper in a dark Room, by means

means of a *Lens* placed at a Hole in the Window-ſhut; for if the Wall or white Paper be at a due focal Diſtance behind the *Lens*, the Picture will be of the ſame Magnitude, both when no Part of the *Lens* is covered, and when it is all covered, excepting only a ſmall circular Space in its *Axis*, anſwering to the contracted Pupil.

I know HONORATUS FABER, in his *Synopſis Optica*, publiſhed *ann.* 1667, endeavours to prove the clear contrary to this my Aſſertion, and that after this Manner: AB (PLATE I. *Fig.* 10.) is an Object, EF the greater Aperture of the Pupil admitting the Projection KI on the *Retina*; whereas the leſſer Aperture CD admits only the Projection GH: But GH is leſs than KI; wherefore a leſſer Aperture diminiſhes the Projection. I admire that any Man that undertook, as this learned Jeſuite, to write of Optics more accurately than all that went before him, ſhould have been guilty of ſo very groſs an Error; and I do yet more admire, that the celebrated GASSENDUS, and with him the noble HEVELIUS, ſhould have been of the ſame Opinion; for tho' the aforeſaid Demonſtration holds moſt certainly true in direct Projections, as in a dark Room with a plain Hole, yet it will not hold in Projections made by Refraction, as in thoſe on the *Retina*, for the Reaſons above noticed, which

are

are too evident to need any further Explanation.

§ 50. It is eaſy to ſee, that what has been juſt now ſaid of the Magnitude of the Pupil's having no Influence on the Magnitude of Objects, holds true only with reſpect to ſuch Objects as the Eye is accommodated to; for all Objects placed without the Limits of diſtinct Viſion, will appear greater or ſmaller according as the Pupil is dilated or contracted; for the Rays that paint the extreme Points of the Object upon the *Retina* (like all the others) in place of being united in a Point in the *Axis* of the Pencil, will now be ſcattered over a ſmall circular Space all round that *Axis*; which Space being greater or ſmaller according as the Pupil is more or leſs dilated, the Image of the Object muſt alſo be greater or ſmaller in the ſame Proportion, and therefore Objects will appear greater, when the Pupil is dilated than when it is contracted.

This is quite contrary to what ÆGINETA, and the other antient Phyſicians, maintain: But as it is agreeable to Reaſon, and the Principles of Optics, ſo it is alſo agreeable to Experience; for a Candle, which, at ſixty Feet Diſtance, commonly appears to a ſhort-ſighted Perſon a luminous Circle of about a Foot Diameter, more or leſs, according to the Degree of ſhortneſs of Sight, and Magnitude of the Pupil;

Pupil; when it is viewed thro' a ſmall Hole made in a Card, it ſeems much leſs than to the naked Eye, becauſe the Luxuriancy of the Image is a good deal corrected by the Smallneſs of the Hole in the Card, which has the ſame Effect on the Image, that the Contraction of the Pupil would have upon it. In like manner the Stars, which to moſt People appear larger than they ought, becauſe the Eye with reſpect to them is ſomewhat purblind, are made much leſs, by being viewed thro' ſuch a ſmall Hole.

## QUERY III.

§ 51. *Whence is it that the Eye ſees beſt from amongſt Darkneſs?*

That the Eye ſees beſt when ſurrounded with Darkneſs, is what every one has often obſerved. From deep Pits the Stars may be clearly ſeen in bright Day-light. This GALEN has taken notice of in the 3d Chapter of his 10th Book *de Uſu Partium;* and every Collier or Miner does daily experience the Truth of it: Neither is it needful to deſcend to the Bottom of a Pit; for if a long Tube be applied to the Eye, the Stars may be ſeen thro' it in Day-light as well as from the Bottom

Bottom of a Pit. But of all the Inſtances of this Kind that I have met with, that which Mr. BOYLE gives us, in his Obſervations on vitiated Sight, is the ſtrongeſt. It is as follows:

A Gentleman of the Army being at *Madrid*, ventured to do his King (CHARLES I.) a Piece of Service of an extraordinary Nature; which being thought very irregular, he was committed to an uncommon Priſon, which had no Window belonging to it, only a Hole in the Wall, at which the Keeper put in Proviſion, and preſently cloſed it again on the Out-ſide, but not perhaps very exactly: For ſome Weeks this Gentleman continued in the dark very diſconſolate, but afterwards he began to think he ſaw ſome little Glimmering of Light, which from time to time increaſed, ſo as he could not only diſcover the Parts of his Bed, and other ſuch large Objects, but at length he perceived the Mice that frequented his Chamber to eat the Crumbs of Bread which fell upon the Ground, and diſcerned their Motions very well. This Relation Mr. BOYLE tells us he had from the Gentleman's own Mouth; and that, after ſome Months, when he was ſet at Liberty, he durſt not leave his Priſon on a ſudden, for fear of looſing his Sight by the dazzling Light

Light of the Day, and therefore accuſtomed his Eyes to it by ſlow Degrees.

Theſe Inſtances are ſufficient to ſhew, that the Eye ſees beſt from amongſt Darkneſs. Why this ſhould happen, is a Problem which AGUILONIUS, in the 61*ſt* Propoſition of his firſt Book, has propoſed to anſwer: But being ignorant of the true Manner of Viſion, it needs be no Surpriſe that he ſhould not ſatisfy.

The true Cauſe of this *Phænomenon* is twofold; the firſt depends on the Mobility of the Pupil, which, by accommodating itſelf, as much as is poſſible, to the Quantity of Light that ſhines upon the Eye, muſt dilate conſiderably when the Eye is in Darkneſs; but, *cæteris paribus*, Objects are always ſeen moſt clearly when the Pupil is dilated, and therefore they muſt alſo be ſeen moſt clearly when the Eye is ſurrounded with Darkneſs. But,

2*dly*, There is yet another Reaſon of this *Phænomenon*; for underſtanding which, I muſt again obſerve, that the adventitious Rays that come from Objects to which the Eye is not directed, by mixing themſelves with the Pictures on the *Retina*, render them confuſed and faint. Thus, when the Image of an external Object is caſt upon a Sheet of white Paper, by means of a *Lens* placed in

a

a Window, the Image will appear very clear and distinct, if the Chamber be close, so as no Light may enter but thro' a small Hole, behind which the *Lens* is placed; but if the whole Window be open, or if otherwise the Room be not perfectly dark, the Image will not be distinctly expressed; but, by being mixed with the adventitious Light of other Objects, will appear weak and confused. The same Thing therefore must happen to the Eye; Objects must always be distinctly painted on its Bottom, when the Eye is surrounded with Darkness, and receives no Light but what comes from the Object in view; and the Object being distinctly painted, it must also be distinctly seen; but when the Eye is surrounded with Light, the Picture will be faint and obscure, because it is then mixed with much foreign Light that does not belong to the Object in view, and therefore the Object will be but obscurely perceived.

## QUERY. IV.

§ 52. *Whence is it that One from within a Chamber sees the Objects that are without, but does not from without see those within?*

There are some Writers of Optics, who have sought for the Cause of this *Phænomenon*

in the Difference which there is betwixt the free Air, and that ſhut up in the Chamber but altogether without Succeſs. For, to diſcover the true Cauſe of this *Phænomenon*, we need only reflect upon what has been juſt now ſaid with regard to the Eye's ſeeing beſt from amongſt Darkneſs; for when one is without, the Objects within the Chamber being but faintly illuminated in compariſon to thoſe that are without, thoſe that are without will excite ſuch ſtrong and lively Motions in the *Retina*, that it cannot at the ſame time be ſenſibly affected by the faint Light of the Objects that are within. And this is one Reaſon why Objects within a Chamber cannot be diſtinctly ſeen from without, unleſs they be as much illuminated as thoſe that are without.

Another Reaſon is, That the Glaſs of the Window reflects a ſtrong Light upon our Eyes while we are without, which hinders the faint Light coming from Objects within the Chamber, from making any ſenſible Impreſſion or Picture on the *Retina*.

But there is yet a *third* Reaſon why Objects within a Chamber are not ſeen from without, namely, When we are without, our Pupils will be contracted, ſo that only a ſmall Portion of that faint Light that is reflected from the Objects within the Chamber is allowed

lowed to pass to the *Retina*. But it happens far otherwise to those that are within the Chamber, and view the Objects that are without; for the Light of the Chamber being faint in comparison with that which comes from without, and passes thro' the Glass, it can never hinder the *Retina* from being sufficiently agitated by the Light that comes from without; and besides, the Pupil will be dilated, by which Means a sufficient Quantity of Light will enter the Eye; for the internal Surface of the Glass can reflect but little Light towards the Eye, because the Light of the Chamber is weak; and therefore the Pupil must dilate, and being dilated, the Impression made on the *Retina* by the Light that comes from external Objects, will be strong and lively; neither will the weak Light, that is reflected from the Glass or other Objects within the Chamber, be able to efface the Images that are thereby painted on the *Retina*.

## QUERY V.

§ 53. *Whence is it that in Candle-light, when one wants to see an Object accurately, it is necessary to hide the Candle with the Hand, by making its Shade fall upon the Eye?*

That this is true, no Body can be ignorant of, that has ever walked in the dark by the Help

Help of a Lantern; for every thing is beſt ſeen, when the Light of the Candle is intercepted, ſo as it may not ſhine upon the Eye.

The Reaſon of this is, that the bright Light of the Candle, not only makes the Pupil contract, but, by mixing itſelf with the Images of the other Objects, it in ſome meaſure obliterates them, ſo as they cannot be ſo well perceived: But, when this adventitious Light is intercepted with the Hand, then the Pupil will widen, and admit a greater Quantity of the Rays that come from the Object we want to ſee, neither will the Image made by theſe Rays be rendered faint or obſcure by being mixed with the Light of the Candle which is now intercepted.

§ 54. From this we may ſee, why thoſe who are in a very bright and reſplendent Air, when they would accurately obſerve any Thing at a great Diſtance, they are obliged to depreſs their Eye-brows, or apply their Hand to their Fore-head, for making a Shade upon their Eyes: And it is altogether idle and ridiculous, to ſearch for the Cauſe of this *Phænomenon* in the Concavity of the Hand directing the Species of Objects, and helping them to enter the Eye, as a great many antient Phyſicians and Philoſophers did imagine.

We may from this alſo ſee, whence it comes to paſs that Hollow-eyed People do for ordinary

nary see much better than others, and especially than those whose Eyes are protuberant; for when the Eyes are hollow or much sunk within the Orbit, they are more in Obscurity, and better shaded from foreign Light that does not belong to the Object in view; whereas, when they are protuberant, more of this foreign Light enters the Eye. I formerly observed, that, when a long Tube is applied to the Eye, the Stars may be seen thro' it in bright Day-light; the Reason of which is, that no foreign Light is allowed to enter the Eye. The same Thing must therefore happen in some measure, when the Eyes are hollow and much sunk in the Socket; for the Edge of the Socket will cast a Shade upon the Eye, and intercept a good deal of that foreign Light that does not belong to the Object in view, especially if the Eye-brows are depressed at the same time; whence it is, that some Hollow-eyed Persons have been able to see the Stars in the Day-time (tho' perhaps not so well as from the Bottom of a Pit, or thro' a long Tube) as PLEMPIUS has observed. But those whose Eyes are prominent can never see the Stars in Day-light; because the foreign Light that shines upon the Eye, not only makes the Pupil contract, by which the Pictures in the *Retina* are rendered more faint and obscure, but, by mixing with the Pictures,

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it weakens them ſo much, that they cannot at all be perceived. But they have a remedy at hand, whereby their Sight may be much helped, which is, to fold their Hand ſo as only a ſmall Hole may be left, thro' which Objects are to be viewed; this forms a Shade upon the Eye, by which their Sight is rendered as good as in thoſe who are naturally Hollow-eyed, unleſs they be alſo ſhort-ſighted; which is indeed very common to ſuch as have prominent Eyes.

## QUERY VI.

§ 55. *Whence is it, that when we have been for ſome Time in a Place much illuminated, and then go into another much leſs bright, or when we go from a Place that is but faintly illuminated into another that is very bright, the Sight, for ſome Time, is much impaired?*

The Anſwer to this is eaſy: For, in an illuminated Place, the Pupil is contracted, that the *Retina* may receive no Injury from the Multitude of Rays; yet it will be very much affected by them, becauſe the Light is ſtrong; and when the Mind has been accuſtomed to theſe greater Motions, it will not for ſome Time be much affected by leſſer ones; and therefore, when, in this Condition, any one ſhall enter a darkiſh Place, as now only

only a very little Light passes thro' the Pupil, the *Retina* will be but little affected by it, and the Mind, having been accustomed to stronger Impressions, will hardly perceive any thing; hence follows some Kind of Blindness, and all things continue obscure till the Pupil by degrees is a little enlarged, and more Light passes thro' it, and the Mind can accommodate itself to milder Impressions.

From this we may see, why it becomes advisable that such as, from a very light House, are obliged to go home in the dark, should keep their Eyes shut for some Time before they go out; for by this Means the Pupil will dilate, so as to enable them to see the Road, and avoid the Precipices and Dangers that may be in their Way. It was by this Method that PLEMPIUS, for his Diversion, imposed so far on some of his Friends, as to make them believe that he saw in the dark, (*Ophthalmograph. lib.* 4. *probl.* 52.); and as he was short-sighted, as he himself tells us, (*Probl.* 17.) he behoved to see with much less Light than others whose Eyes are good, which would contribute a good deal to forward the Deceit. Mr. DU FAY also, by this Method, could see the weak Light of Diamonds in a dark Room, which could not be seen, when he entered the Room with both Eyes open; as has been before observed.

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On the other hand, in coming ſuddenly from among Darkneſs into Light, we cannot for ſome Time ſee any thing right, becauſe we are not able to bear the Light which enters the dilated Pupils in too great Plenty, and produces a painful Agitation in the *Retina*. Hence it is, that thoſe who, from deep Caves or Pits, come into the Light, ought to be careful not to advance too faſt, leſt they loſe their Sight by the ſudden Influx of Light. There is a remarkable Inſtance of this to be ſeen in GALEN; for, in his 10th Book *de Uſu Partium*, he tells us of ſome miſerable Captives, whom DIONYSIUS the Tyrant of *Sicily* uſed to bring forth, from the dark Dungeon in which they were confined, into a white well lighted Room, and who, not being able to bear the ſudden Tranſition from Darkneſs to ſo bright a Light, were thereby immediately blinded.

## QUERY VII.

§ 56. *Whence is it that ſome People ſee in the Dark?*

We do not here inquire, why lucid or illuminated Objects are ſeen by Night, when the Eye is involved in Darkneſs; but our Meaning is, to account for the Appearance of Objects in

in the Night-time when they are neither lucid nor illuminated.

That Cats, Mice, Rats, Owls, and Bat-birds, do ſee in the dark, has never been doubted; but whether the ſame Thing does ever obtain in Man, has been diſputed, and is not ſo univerſally believed: Yet the Fact has been ſo often atteſted, and that by Perſons of undoubted Probity, that none but an intire Sceptic can withhold his Aſſent. Thus, PLINIUS and SUETONIUS tell us, that TIBERIUS CÆSAR had his Eyes ſo made, that being wakened in the Night-time, he ſaw every Thing as clearly as if they had been illuſtrated with bright Light, but that in a little they gradually grew fainter and fainter, till at laſt they diſappeared. And the ſame Thing is alſo told of ALEXANDER. ASCLEPIODORUS the Philoſopher is ſaid to have read Books in the Night-time, without the Aſſiſtance of a Candle, or any other Light. And HIERONIMUS CARDANUS, that noble Mathematician and Profeſſor of Phyſic at *Bulloigna*, who is yet famous for ſome of his Writings, aſſures us, that, when he was young, he needed not the Aſſiſtance of a Candle to read in the dark. CÆLIUS RHODIGINUS affirms the ſame Thing of himſelf, and takes GOD to Witneſs the Truth of what he writes. BRIGGS, WILLIS, SCHENKIUS, PLATERUS, AQUAPENDENT,

and many other medical Writers, mention others much in the same Circumstances: And the Instance formerly given from BOYLE, of an Officer in the Army, who, being thrown into a dark Prison, into which no Light was allowed to enter, came at length to see the Mice that frequented his Chamber, is a further Proof of the same Thing. And now indeed I find, that this Faculty of Seeing in the dark has been pretty familiar to many great and learned Men, such as both SCALIGERS, JULIUS CÆSAR the Father, and JOSEPHUS JUSTUS the Son, CASAUBON, JOANNES BAPTISTA PORTA, SABELLICUS the Historiographer, *&c.* If any yet desire further Satisfaction in this Point, they may consult JOSEPH SCALIGER on the Life of his Father, and BARTHOLINE *de Luce Animalium:* But, for my Part, I think what hath been said sufficient. Let us now inquire into the Cause of this strange and uncommon *Phænomenon*.

§ 57. That Light is a necessary Condition for Vision, no Body ever doubted. But it has been disputed, whether it be necessary, considered as belonging to the Object, or as belonging to the Eye, or as belonging to both. A great many of our antient Physicians, as well as Philosophers, were of Opinion, that either the Light of the Object, or that of the Eye, was sufficient for seeing Objects; for they imagined that Vision was produced

produced by a continual Emanation of certain Species or Images, which they ſuppoſed were conſtantly emitted to the Eye from the Object, and that Light only ſerved to illuminate them and render them ſenſible: And thus they accounted for nocturnal Viſion from the inherent Light of the Eyes illuſtrating the Species of Objects, that, with them, do conſtantly flow into the Eye, by Night, as well as by Day. To confirm this Hypotheſis, they obſerve, that Cats, Owls, and ſuch like nocturnal Animals, have Eyes that ſhine in the dark; and, from this Radiation of their Eyes, they conclude, that they are poſſeſſed of an inherent Light, whereby the Species of Objects may be diſcovered. But this Hypotheſis, however ſpecious, can only ſatisfy ſuch as are Strangers to our more modern Diſcoveries. For,

1*ſt*, Tho' the Eyes of nocturnal Animals appear bright and reſplendent in the dark, yet this does not proceed from any inherent Light in the Eyes, but from a faint Light that ſtill remains in the Place, which being reflected by the *Tapetum* in the Fund of the Eye, becomes viſible; for, in ſuch Animals, the Pupil being extraordinary large, admits a great deal of Light, and the *Tapetum*, which in other Animals is black, or of a dark Colour, in them is of a fine reſplendent Sky-blue, or other

other bright Colour, by which all the incident Light is reflected in the ſame manner as by a concave Mirror that is well poliſhed:

That this is true, is manifeſt from the following Experiment: Take a Cat, and ſhut her up in a very cloſe Room, into which no Light enters; and having brought in a dark Lantern with a Candle burning in it, if the Lantern be exactly ſhut, and have a Cloth covering it, the better to prevent any Light's getting into the Room, the Eyes of the Cat will not appear. But as ſoon as the Lantern is a little opened, that a little glimmering Light may be ſent into the Room, tho' the Room appear ſtill dark, yet you ſhall then obſerve two bright Lights in the Corner of the Room ſhining like Candles, which are nothing but the Eyes of the Cat illuminated by the faint Light of the Lantern; for, ſo ſoon as the Lantern is again exactly ſhut, theſe Lights diſappear.

This Experiment was made by the famous Bohn Profeſſor at *Leipſick*, a Man of undoubted Veracity, as well as Learning, and therefore may ſafely be relied on. (See his *Circulus Anatomicus*, *Progymnaſma* xxvii.) And we have another Experiment to the ſame Purpoſe in Van Helmomt (*de Form. Ortu*, *Sect.* 50.) which I need not relate.

But,

But, *2dly*, Allowing that there is an inherent Light in the Eyes of nocturnal Animals, yet this Light would be so far from helping them to see by Night, when the Light is faint, that it would very much darken their Sight, even in the Day-time, by effacing the Images painted on the *Retina*. Thus we see that the Images of external Objects cast upon a Sheet of white Paper, by means of a *Lens* placed at a Hole in the Window-shut of a dark Chamber, are rendered weak and faint, by the Admission of Light: And it is for this Reason that provident Nature has darkened the internal Eye, by clothing it with opaque Tunicles, only pierced with a small Pupil for admitting a sufficient Quantity of Light from the Object in view. PLEMPIUS, to evite the Force of this Objection, abandons the Opinion of the GALENISTS, who thought that this inherent Light was lodged in the Crystalline, with them also the immediate Organ of Vision; and maintains that it proceeds from the external Surface of the *Iris*, and that it illuminates the Species as they enter the Eye, without illuminating the inward Eye itself. But, to this I answer, that, were the inherent Light of the *Iris* sufficient for Vision, without any Illumination of the Object, then all of us would see Objects in the dark, by placing a Candle near our Eyes, for illuminating the dark Species as they enter the Eye;

Eye; which is contrary to Experience. And beſides, this Notion of Species or Images that are ſuppoſed to proceed conſtantly from Objects by Night, as well as by Day, is now well known to be but a learned Romance, that has no Foundation in Nature: From all which it follows, that nocturnal Viſion does never proceed from any inherent Light in the Eyes: It is always neceſſary that the Objects themſelves be more or leſs illuminated; and tho' we cannot ſee in the Night-time, yet it does not from thence follow, that there is then an intire Privation of Light, or that Objects are not at all illuminated, but only that the Light is too faint and languid to produce that Motion in our *Retina*'s that is neceſſary for Viſion; and, on the contrary, when others are able to read by Night, as well as by Day, this can proceed from nothing but ſome very favourable Diſpoſition in their Eyes, whereby they are rendered ſenſible of the Impreſſions of the weakeſt Light.

§ 58. Wherein this lucky Diſpoſition conſiſts, we think may be reduced to three Heads:

1*ſt*, They muſt have the *Retina* very tender and delicate; this will render it ſenſible of the fainteſt Rays.

2*dly*, They muſt have the *Cornea* and Humours of the Eye very clear and tranſparent, that

that none of the Light may be intercepted, but that all of it may freely paſs to the *Retina*; for when Light paſſes thro' a thin Plate of pure Glaſs, it is found, by Experience, that at each of its Surfaces about a ninth or tenth Part of the incident Light is reflected; which ſhews that a good deal of the Light which falls on the Eye muſt be reflected back at the external Surface of the *Cornea*, and at both Surfaces of the Cryſtalline, unleſs when the *Cornea* and Humours of the Eye are made very clear and tranſparent. The following Experiment will throw ſome Light upon this Matter:

Upon a Table place two Candles of equal Height, and burning with equal Brightneſs, at equal Diſtances from a Sheet of white Paper, and ſet a Book upright between one of the Candles and the Paper, ſo as it may cut off the Light of that Candle from the one Half of the Paper, while the other Half is illuminated by both Candles. By this Means one Half of the Paper will be twice as luminous as the other Half. Then take a flat thin Piece of clear Glaſs, and hold it in ſuch Manner as to look perpendicularly thro' it at the more luminous Half of the Paper, the other Eye being ſhut, and to ſee the other Half of the Paper with the ſame Eye beſide the Glaſs. In doing this, you ſhall obſerve, that the more luminous Half of the Paper ſeen perpendicularly

larly thro' the Glaſs, appears much brighter than the other Half of the Paper ſeen with the bare Eye on the Side of the Glaſs; conſequently leſs than Half the Light is reflected back from the two Surfaces of the Glaſs, and more than Half is tranſmitted thro' thoſe two Surfaces to the Eye. And the ſame Thing happens, when another Piece of Glaſs is held parallel to the firſt Piece, ſo as to look thro' them both at the more luminous Half of the Paper.

But, in looking thro' three ſuch Glaſſes in the ſame Manner, Dr. JURIN found, that the two Halfs of the Paper appeared nearly of the ſame Brightneſs; conſequently, about Half the Light is reflected back by the three Glaſſes put together.

Now, if we ſuppoſe that at each of the ſix Surfaces a certain proportionable Part of the incident Light is reflected, and the reſt tranſmitted; and that one Half of the whole Light is reflected back from the ſix Surfaces put together, and that the remaining Half is tranſmitted thro' the laſt Surface to the Eye, as is agreeable to the above Experiment: Then, calling the whole Light 1, and the Part reflected back at the firſt Surface $x$; the Part tranſmitted thro' that firſt Surface ſhall be $1-x$; the Part tranſmitted thro' the 2d Surface $\overline{1-x}^{2}$; the Part tranſmitted

tranſmitted thro' the 3d, 4th, 5th, 6th Surfaces, $\overline{1-x}^3$, $\overline{1-x}^4$, $\overline{1-x}^5$, $\overline{1-x}^6$ reſpectively: But the Part tranſmitted through the ſixth Surface to the Eye, being $\frac{1}{2}$ or 0.5, it follows, that $\overline{1-x}^6 = 0.5$; or $1 - x = \sqrt[6]{0.5}$, whence $x = 1 - \sqrt[6]{0.5}$, $= 0.10918$; that is, about $\frac{11}{100}$ of the incident Light is reflected back at the firſt Surface, which is about $\frac{1}{9}$ Part of the whole Light, and about $\frac{89}{100}$ is tranſmitted through that Surface.

3*dly*, and *Laſtly*, thoſe who ſee in the dark muſt have the Pupil very moveable; by this they can adapt it to the Strength and Weakneſs of the Light. Thus Cats, who ſee both by Day and Night, have their Pupils ſo moveable, that they can ſhut them up ſo cloſe, as to admit of, as it were, only one ſingle Ray, and, by throwing all open, they can take in the fainteſt Rays. This is an incomparable Proviſion for ſuch Animals as have occaſion to ſee both by Day and Night; and we are of opinion, that ſome ſuch Mobility does alſo obtain in human Eyes that ſee in the Dark. Neither is it alone ſufficient, that their Pupils be wider than ordinary, as Dr. Brigg's inſinuates (*Ophthalmograph. Cap.* 5. § 12.) His Words are: *Virum ſane calidæ indolis novi, in Comitatu Bedfordienſi degentem, qui oculis felineis donatus eſt: adeo ut epiſtolam,*

*mire admodum in loco obſcuro* (*ubi eadem mihi vix apparuit*) *perlegit. Hujus vero oculi* (*niſi quod pupillas inſigniores obtinuere*) *ab aliorum formatione neutiquam diſcrepabant.*

But, it is more than probable, that, had the Doctor examined his Eyes with more Care, he would not only have found his Pupil large, but alſo exceedng moveable; for, without ſuch a Mobility, it ſeems impoſſible that one who ſees by Night ſhould be able to bear the ſtrong Light of Day, and therefore would be obliged to hide himſelf therefrom, like the Owl and Bat-bird, that ſee in the dark, becauſe their Eye is almoſt all Pupil, but cannot ſuffer Day-light, becauſe their Pupils do not contract ſo much as is neceſſary for enabling them to bear ſo ſtrong a Light.

## QUERY VIII.

§ 59. *Whence is it, that when there is an opaque round Spot, or partial Cataract in the Middle of the Cryſtalline, exactly behind the Pupil, but a little leſs, the Eye thus affected cannot at all ſee in bright Day-light, but in Twilight does ſee, tho' faintly?*

The Reaſon of this is, that tho' the Opacity of the Speck be ſuch as would deprive the Eye of

of Sight, did it extend over the whole Pupil, yet it does not altogether hinder the Rays from getting to the *Retina*; and therefore, in Day-light, the Pupil will be made to contract by the Rays that pass thro' the Speck, in like manner as it contracts in Cataracts, when the whole of the Crystalline is affected; and the Pupil being contracted, all the Rays that pass thro' it, will fall on the opaque Spot, and will not paint any Picture upon the *Retina*; whence every thing becomes invisible, just as in a Cataract, when the whole of the Crystalline is opaque: But, in the Twilight, the Pupil dilates; and therefore the Rays, which pass furthest from its Centre, will not fall upon the opaque Spot, but will be transmitted to the *Retina* in the usual manner, for painting thereon the Images of external Objects; which will therefore become visible. But, because of the Interception of the Rays next the Centre of the Pupil which fall on the Spot, Objects will appear more faint and obscure than they would have done had the Eye been sound. This I take to be the chief Cause of the *Nyctilopia* of HIPPOCRATES, which may take place, tho' the Speck be not so opaque as to be visible, and which therefore may pass unobserved; for we find in Cataracts that the Sight is greatly impaired, even when the Opacity of the Crystalline scarce exceeds that of Smoke, and does not

appear

appear to common Obſervers: But if this Speck be conſiderably leſs than the Pupil, the Eye muſt ſee by Day as well as in the Twilight; for tho' the Pupil is made to contract by the Light of Day, yet it will not contract ſo much, but that ſome of the Rays, next its Circumference, will paſs to the *Retina*, without falling upon the Speck. And from this we may ſee, how, from ſuch a Speck, according as it is ſmaller or greater, we may, in Day-light, either ſee better or worſe, or not at all; and when we can ſee in Day-light, the Sight may be either equal to what it is in Twilight, or ſtronger or weaker in any Proportion. And what has been ſaid of a Speck in the Cryſtalline, will alſo hold when ſuch a Speck is on the *Cornea*.

§ 60. GALEN imagined, that, from ſuch a Speck in the Middle of the Pupil, Objects appear perforated with a Hole in their Middle, correſponding to the Magnitude of the Speck; and in this he has been followed by almoſt all Phyſicians, till of late, that Optics come to be better underſtood by them. *Si in Pupillæ centro* (ſays he, *de Symptom. Cauſ. Lib.* 1. *Cap.* 2.) *exigua conſiſtit ſuffuſio, partibus quæ in circuitu ſunt manentibus puris, omnia iis qui ita laborant, veluti feneſtras habere videntur; nam id quod in medio non videtur, exciſum eſſe putatur.* Theſe are GALEN's Words, as they ſtand

ſtand in the Tranſlation. But, from what I have formerly ſaid, (to which the Reader may have Recourſe) it is evident, that, from ſuch Specks, no Hole or dark Spot will be ſeen in the Object, excepting only when the Eye is remarkably myopical or preſbytical.

## QUERY IX.

§ 61. *Whence is it, that, when the Half of the Pupil is obſtructed by a Speck on the* Cornea *or Cryſtalline, the Eye ſo affected, ſees Objects coloured at their Edges, as when ſeen thro' a Priſm?*

The Reaſon of this is, that the diaphanous Part of the Cryſtalline, thro' which the Rays paſs, is like a Wedge or Priſm, being thick in one place and thin in the oppoſite one; and therefore the Rays, by their unequal Refraction, muſt be ſeparated into Colours, in like manner as they are ſeparated when they paſs thro' a Priſm; neither will theſe Colours be diluted, by being mixed with the intercepted Rays, which, had there been no Speck, would have been refracted the contrary way. And this alſo is the Reaſon, that an Object which appears double when viewed thro' two ſmall Holes in a Card, is then alſo ſeen coloured.

§ 62. Many antient Phyſicians affirm, that when the Half or any Part of the Pupil is obſtructed

obſtructed by ſuch a Speck, a ſimilar Part of the Object will be darkened; having been led into this Miſtake by what GALEN ſays of Object's appearing perforated, when there is a circular Speck in the Middle of the Pupil. But, ſince I have already ſhown, from the Principles of Optics, that no Speck in any part of the Pupil can darken any one Part of the Picture on the *Retina* more than another, unleſs the Eye be remarkably preſbytical or myopical; it follows, that no Part of the Object can appear dark or wanting from any ſuch Speck or Obſtruction; and if any one deſires an experimental Proof of this, he needs only darken any Part of a *Lens*, by applying Patches or ſuch like ſmall opaque Bodies, and by means thereof caſt the Image of any Object without Doors on a Sheet of Paper, in a dark Room; for, if the Paper be at a due focal Diſtance from the *Lens*, no Defect or Spot will be found in the Picture: And, were it otherwiſe, Cats would be liable to ſuch a Depravation of Sight, as would render their Eyes almoſt uſeleſs to them; for their Pupils are ſometimes large and circular, and at other times contracted into a long narrow Fiſſure, which would have a prodigious Effect on the Magnitude and Figure of Objects, did their Magnitude and Figure depend on the Magnitude and Figure of the Pupil: But this Change in their Pupils has no ſuch Effect; all that it does is to render Objects more or

leſs

leſs bright, according as the Pupil is more or leſs dilated; for the Rays that come from the ſeveral Points of the Object being ſo refracted, as to meet again at ſo many correſponding Points in the *Retina*, it is evident, that every Point of the Picture is formed by a diſtinct Cone or Pencil of Rays, whoſe common *Baſis* is the Pupil; and therefore, tho' ſome of the Rays belonging to each Pencil be intercepted, either by the Contraction of the Pupil, or by a Speck in any Part of it, yet no one Part of the Picture will be more darkened than another, and conſequently no Defect will be ſeen in the Object. And this is the true Reaſon why the Figure or Magnitude of Objects are never affected by any Alteration made in the Figure or Magnitude of the Pupil; of which many Inſtances might be given. PLEMPIUS, in his *Ophthalmographia*, (*Problem.* 24.) tells us of ſeveral who had one of their Pupils obſtructed, ſo as only a ſmall Creſcent, ſimilar to the illuminated Part of the new Moon of three or four Days old, was left free, to whom every thing appeared of the ſame Magnitude and Figure as to others. And, in the ſame Treatiſe (*Lib.* 3. *Cap.* 8.) he gives us the like Inſtance in a Woman, who had one of her Pupils oval. His Words are: *Vidi ego et novi matronam, cujus ſiniſtri oculi pupilla a primordiis ovalis erat, videbat tamen res uti nos.* And BARTHOLINE alſo, in the *Acta Hafniæ* (*ann.* 1671 and

and 1672, *Observ.* xxx.) gives us a similar Case, in a young Man, who from his Birth had the Pupil of the Left-Eye of an oblong irregular Figure, and yet he saw Objects with it the same as with the other. Many more Observations of the like Kind might be given; but more, I think, are unnecessary.

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## CHAP. VI.

### *Of the Use of the Black Pigment covering the* Uvea *and* Choroides.

HAVING, in the preceeding Chapter, inquired into the Use of the Pupil, and the Benefits we receive from its Motions, what falls next in order to be explained, is the Utility of that black Pigment, wherewith both Sides of the *Uvea* and *Choroides* are for the most Part covered.

SECT. 1. *First* then, the *Uvea* is covered with this black Pigment, that it may be rendered the more opaque, for the better hindering any Light to enter the Eye, but what passes the Pupil; for no thin Membrane is altogether opaque, unless it be of a black Colour, even our Eye-lids themselves allow a good deal of Light to pass, as every one may find, by

by looking to the Sun with his Eyes ſhut; it was therefore neceſſary that the *Uvea* ſhould be covered with this black Colour, that the Eye might be a *Cellula Obſcura*, and that no Rays might enter it but by the Pupil; for were the *Uvea* tranſparent, the Pictures of external Objects made on the *Retina* would become faint and confuſed, by being mixed with the adventitious Rays that come from other Objects to which the Eye is not directed. This is evident from the Experiment ſo often mentioned, of caſting the Images of external Objects upon a Sheet of white Paper, by means of a *Lens* placed in the Window; for if the Chamber be cloſs, ſo as no Light enters it, but thro' a ſmall Hole behind which the *Lens* is placed, the Image of the external Object will appear exceeding diſtinct; but if more of the Window be open, the Image, by being mixed with the foreign Rays belonging to other Objects, will be rendered ſo faint and imperfect, as ſcarcely to appear. But,

§ 2. 2*dly*, This is not all; there is yet a very conſiderable Advantage received from the Pigment with which the Inſide of the *Choroides* is tinged; for the Rays of Light which fall thereon, after having paſſed thro' the *Retina*, are ſtiffled and loſt, which otherwiſe would be reflected back, to and again, upon the *Retina*, and, by being mixed and

confounded with the Image of the Object, would render it confuſed and indiſtinct. And this is one Reaſon why Man and Birds ſee better and more diſtinctly than the greateſt Part of other Animals, who have this Tunicle of another Colour. This may be illuſtrated, by the *Camera Obſcura*, ſo often mentioned, in which the Pictures caſt on the white Paper will be made more lively and perfect, if the Walls of the Room are painted Black, or hung with black Cloth, ſo as to reflect no Light upon the Picture, But,

§ 3. 3*dly*, If we conſider that the Back-ſide of the *Choroides* next to the *Sclerotica* is likewiſe covered with this black Pigment, and that in all Animals, even thoſe which have its concave Side next the *Retina* of another Colour, as AQUAPENDENT, in his Treatiſe *de Oculo*, (*Cap.* iv. *Sect.* 1.) obſerves, we cannot but think that it likewiſe contributes to the Preſervation of that Tranſparency in the Humours which is abſolutely neceſſary for the Tranſmiſſion of Light; and that becauſe there appears no other Reaſon for this black Colour upon the black Part of the *Choroides*. Thus the Lion, Camel, Bear, Ox, Dear, Sheep, Dog, Cat, and many other Quadrupeds, and even ſome of the Bird-kind that are not endowed with a good Sight, ſuch as the Owl and other nocturnal Birds, which have the Inſide

ſide of the *Choroides* of a blue, green, yellow pearl, or other bright reſplendent Colour, are never found to want a conſiderable Quantity of this black mucous Pigment upon the convex or Back-ſide of this Membrane, which can ſerve for nothing elſe, but for rendering the Aliment, which goes to the Cryſtalline and other Humours of the Eye, more pure and free from the groſs black Parts, which might render them opaque and unfit for tranſmitting the Light.

It therefore ſeems neceſſary, that the *Uvea* and *Choroides* ſhould be provided with Glands proper for ſecerning this black *Mucus*, that the *Cornea* and Humours of the Eye may not be tinged with any Opacity; for, as in the Jaundice, the whole Body becomes yellow, by Reaſon of the Bile which is not duly ſecerned in the Liver; ſo it is not to be doubted, but the *Cornea* and Humours of the Eye would ſoon loſe of their Tranſparency, were it not for the ſecretory Power of the *Uvea* and *Choroides*, by which the Blood which goes to their Nouriſhment is freed of its moſt opaque and black Parts: Whence it is that Animals, whoſe Blood abounds moſt with blackiſh Particles, have this Membrane proportionally of a more intenſe black Colour; for it is obſervable, that thoſe who have moſt Blackneſs in their Hair or Feathers, have this Membrane alſo moſt black.

§. 4.

§ 4. There is a Mechaniſm not unlike this very remarkable in the *Sepia* or Cuttle-fiſh, a Fiſh well known in the Apothecary-Shops, from a Kind of Shell commonly called *Os Sephiæ*, wherewith its Back is covered. This Animal is provided with a Bag towards the Throat near the Stomach, whoſe Uſe is to ſeparate and contain all the opaque black Particles of its Blood and Humours. And this is the Reaſon that the Subſtance of this Fiſh is of a white Colour, which otherwiſe would probably have been black; for the Humour contained in this Bag is ſo very black, that it exceeds even that of Ink itſelf, and one Gut thereof is ſufficient to blacken many Baſons of Water; Whence it is that this Fiſh does eaſily ſave itſelf from Fiſhers, and other Fiſh that ſeek to devour it, by expreſſing a little of this Liquor into the Water in which it ſwims; and therefore PLUTARCH very agreeably ſays, that this Fiſh imitates what HOMER makes the Gods do, to hide and deliver their Friends from the Danger to which they are expoſed in Battle, which is, to cover them with a dark Cloud, that they may eſcape ſafe.

Now, as the Subſtance of this Fiſh becomes white, from the Separation of all the opaque black Particles contained in its Blood and Humours, ſo it is more than probable, that the *Cornea* and Humours of the Eye retain their

their Tranſparency, becauſe the Blood which goes to their Nouriſhment is, by the ſecretory Power of the *Choroides* and *Uvea*, freed of all thoſe opaque black Particles which could in the leaſt tarniſh them, or diminiſh their pure Tranſparency. And this may poſſibly be one Reaſon why thoſe Creatures that ſee beſt, ſuch as Eagles and other Birds of Prey, have the Pupil very black; and, on the contrary, the Owl, Lyon and other Animals, whoſe Sight is not ſo good, have this Hole leſs black, becauſe the Bottom of their Eyes is not covered with this black Pigment.

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## CHAP. VII.

### *Of the Uſe of the* Retina *and Optic Nerve.*

SECT. 1. FROM what hath been above explained, concerning the ſeveral Offices of the principal Parts of the Eye, it is eaſy to ſee how all concur in painting the diſtinct and lively Images of external Objects upon the *Retina*. What falls next in order to be conſidered, is, the Uſe of the *Retina*

*Retina* itſelf, and of the optic Nerve, of which it is an Expanſion.

The *Retina* then ſerves for receiving the Images of external Objects painted thereon, and to propagate the Impreſſions made thereby thro' the ſmall Fibres of the optic Nerve into the common Senſory, or that Part of the Brain in which all the Fibres of our Nerves terminate, and in which our Mind reſides, by which Means the Ideas of Objects are excited in the Mind.

§ 2. The Connection betwixt theſe Ideas and the Motions or Agitations excited in the *Retina*, optic Nerves and *Senſorium*, is unknown to us; neither need we ever expect to diſcover it: It is ſufficient that we know, by Experience, that the Union of the Body and Mind is ſo ſtrict, that ſome Motions in the Body do, as it were, cohere with certain Ideas in the Mind, ſo as they cannot be ſeparated from each other, tho' we cannot find any thing common between them, nor ſo much as perceive that any Connection is poſſible; for there are a great many Things which do always follow others, without any proper Caſuality in that which goeth before, and which have no Manner of Connection with each other, but in the Will of God, who makes them accompany each other. And of this Sort the Senſations of our Mind ſeem to be

be one; for it does not at all ſeem poſſible, that the Motions excited in the *Senſorium*, by Objects acting upon our Organs of Senſe, can be the true phyſical or efficient Cauſe of the Senſations ſaid to be excited by them; but only the occaſional Cauſe which determines the Author of Nature, or ſome ſubordinate active Being acting under him, and by his Appointment, to produce theſe Senſations in the Mind, when that occaſional Cauſe takes Place.

§ 3. It is now, I think, an agreed Point, that Senſation, Perception, and Thinking, cannot poſſibly be a Mode of Motion, nor of Figure, nor of any other Property or Power of Matter, and that for this obvious Reaſon, becauſe the Idea of Perception, Senſation, and Thinking, and the Idea of Motion or of Figure, or of any other Property or Power of Matter, have not the leaſt Likeneſs or Affinity between them: For every Mode of any Power or Quality, is nothing elſe but that Power or Quality of which it is a Mode, underſtood with ſome particular Limitation; that is to ſay, its nothing but a particular Inſtance of that general Power or Quality; nothing but the general Power or Quality itſelf, conſidered under this or that particular Modification: Blue and Red, and all other Modes of Colour, are nothing but ſeveral particular Colours, and can contain nothing in

in their Idea beyond the *Genus* of Colour. Acute and Grave, and all other Modes of Sound, are nothing but several particular Sounds, and can contain nothing in their Idea beyond the *Genus* of Sound. In like Manner, Circular and Triangular, and all other Modes of Figure, are nothing but several particular Figures, and can contain nothing in their Idea beyond the *Genus* of Figure. So all Modes of Motion are nothing else but merely particular Motions, and cannot contain any thing in their Idea beyond the *Genus* of Motion. And therefore, if simple Ideas be the best Foundation of all our Knowledge, and clear and distinct Perception of the Agreement or Disagreement of those Ideas, be the best and greatest Criterion of Truth that our Faculties enable us to attain to, then it is as evident as any Truth can be, that Sensation, Perception, or Thought, cannot possibly be a Mode of Motion or of Figure, or of any other Property or Power of Matter, and that because there is evidently something in the Idea of Perception, Sensation, and Thought, besides and beyond the *Genus* of Motion or of Figure, or of any other Property or Power of Matter. And I have exactly the same intuitive Certainty of this, as I have, that an acute Sound is not a purple Colour, or that a quick Motion is not a sweet Taste, or

that

that a Triangle is not a burning Heat, or that any one Thing in the World is not another whose Idea is the remotest and most distant from it that can be imagined.

§ 4. Now, since Sensation, Perception and Thought, cannot possibly belong to Matter, it seems evident, that the Matter of the *Sensorium*, however moved or agitated by Objects acting on our Organs of Sense, can never produce or be the true efficient Cause of the Sensations in our Mind; and that for this plain Reason, That no Effect can have any Perfection or Excellency, which was not either actually in the Cause, or at least in a higher Degree. All possible Changes of Figure are still nothing but Figure; all possible Variations, Compositions, and Divisions of Magnitude, are still nothing but Magnitude; all possible Compositions and Effects of Motion, are still nothing but mere Motion; all Compositions of Magnitude, Figure and Motion together, are still nothing but Magnitude, Figure and Motion: And how many other Qualities soever, known or unknown, the Particles of Matter, of which our *Sensorium* consists, be supposed to be endowed with, those Qualities can never in any Composition or Division, produce Sensation or Thought, or any new Power, Quality or Perfection, specifically different from themselves, either in the *Sensorium* itself, or in the Mind

reſiding in it, unleſs a Cauſe could give more to the Effect than is in itſelf.

That which hath been apt to deceive Men in this Matter, is this, that they imagine Compounds to be ſomewhat really ſpecifically different from the Thing of which they are Compounded; which is a very great Miſtake. For all the Things of which Men ſo judge, either (if they be really different) are not Compounds or Effects of what Men judge them to be, but are ſomething totally diſtinct; as when the Vulgar think Colours and Sounds to be Properties inherent in Bodies, when indeed they are purely Thoughts in the Mind; or elſe, if they be really Compounds and Effects, then they are not different, but exactly the ſame they ever were; as when two Triangles put together make a Square, that Square is ſtill nothing but two Triangles; or when a Square cut in Halves, makes two Triangles, theſe two Triangles are ſtill only the two Halves of a Square; or when an Acid and Alkali mixed together make a Neutral Salt, that Neutral Salt is ſtill nothing but Acid and Alkali intermixed, and which may be again ſeparated; or when a Mixture of Blue and Yellow Powder makes a Green, that Green is ſtill nothing but Blue and Yellow intermixed; as is plainly viſible by the help of Microſcopes: And in ſhort, every Thing, by Compoſition, Diviſion

or

or Motion, is nothing elſe but the very ſame Thing it was before, taken either in whole or by Parts, or in different Place or Order, ſo as to excite in our Minds different complex Notions, and occaſion new abſtract Names of Things; but by no Means to produce any new Quality, Power or Perfection, either in the Things themſelves, or in any thing elſe, ſuch as Senſation, Perception and Thought, are agreed to be, inhering truly and properly in the Mind as their only Subject.

§ 5. Now, ſince Senſation, Perception and Thought, are Qualities and Perfections that cannot be produced in the Mind by the Motions excited in the *Senſorium*, or by any other material Cauſe whatever, what way ſoever moved, compounded, divided or modified; it follows, that they muſt be produced by the powerful Influence and Operation of ſome immaterial active Cauſe, which is itſelf actually poſſeſſed either of ſuch Qualities, Powers and Perfections, or at leaſt in a higher Degree; and conſequently they muſt be produced, either by the Mind itſelf, or by the Power of God, or ſome other intelligent active Being acting under him, and by his Appointment.

§ 6. That the Mind does, of itſelf, think, by virtue of the active Power it is poſſeſſed of, is undeniable: But to affirm, that, of itſelf, it

it produces that Species of Thought which we call Senſation, ſeems very improbable; for ſince all our Senſations have a fixt and determined Connection and Agreement with the external Objects occaſioning them, and of which they are the Senſations, it is not eaſy to conceive how the Mind ſhould excite and produce in itſelf that determined Senſation, which belongs to the Object, without firſt knowing the Object itſelf, of which the Senſation is to be produced; which it cannot do, becauſe it has not as yet any Senſation or Idea of it.

We are taught by Experience, that we cannot even produce the Senſation of an Object of which former Senſations have lodged the Idea in our Memory; as for inſtance, I cannot at Pleaſure, by any Effort whatever, excite in my Mind the viſible Idea or Senſation of my Dog, Cat, or any thing elſe that is beſt known to me, tho' I have an exact Pattern of them in my Memory, conform to which the Senſation is to be produced: And this being ſo, the Mind certainly can much leſs excite in itſelf the Senſation of any Object not yet known. A Painter may as well Paint an exact Picture of an *Indian* Animal or Plant which he does not ſee or know, as a Man may form a Senſation in his Mind of any Object agreeable to the Object itſelf, without firſt

firſt knowing the Object of which he is to form the Idea or Senſation. From all which, we conclude, that it does not at all ſeem poſſible, that the Motion excited in the *Senſorium*, by Objects acting on our Organs of Senſe, can be the true phyſical or efficient Cauſe of the Senſations ſaid to be excited by them, but only the occaſional Cauſe which determines the Author of Nature, or ſome ſubordinate active Intelligence acting under him, and by his Appointment, to produce theſe Senſations in the Mind, when the occaſional Cauſe takes place.

§ 7. It falls here to be obſerved, that tho' the *Retina* be expanded upon the whole Bottom of the Eye, as far as the *Ligamentum Ciliare;* yet it is not all equally ſenſible.

This appears evidently, when we view any long Word, ſuch as *Mathematician;* for if the Eye be directed to the firſt Letter *M*, and keep itſelf fixed thereon for obſerving it accurately, the other Letters, eſpecially thoſe towards the End of the Word, will not at the ſame Time appear clear and diſtinct. The Reaſon of which is, becauſe the Pencils of Rays that come therefrom, fall too obliquely on the Eye to be accurately collected in diſtinct Points on the *Retina*; but chiefly becauſe of a certain Degree of Hardneſs, Calloſity or Inſenſibility, in all Parts of the *Retina*, excepting towards the *Axis* of the Eye, directly

ly oppoſite to the Pupil. Hence it is, that, when we view any Object, we turn our Eyes directly towards it, that its Picture may fall preciſely upon that moſt delicate and ſenſible Part of the *Retina*, which is naturally in the *Axis* of the Eye; but if this moſt ſenſible and delicate Part of the *Retina* ſhould, from a Fault in the firſt Conformation, or from any other Cauſe, happen to be placed, not in the *Axis* of the Eye, but a little off at a-ſide, then, to ſee any Object diſtinctly, and thence to receive the ſtrongeſt and moſt lively Impreſſions, the Eye muſt not be directed towards it, but a little to a-ſide, that the Object may have its Picture made upon the moſt ſenſible and delicate Part of the Organ. This I had Occaſion to notice before, and ſhewed how it might be one Cauſe of Squinting, which, as is eaſy to ſee, muſt be altogether incurable, when it proceeds from this Cauſe.

§ 8. Now, tho' it is certain, from the above Experiment, that only a very ſmall Part of any Object can be ſeen diſtinctly at a Time, namely, *that* whoſe Image on the *Retina* is in the *Axis* of the Eye, and that the other Parts of the Object, which have their Images painted at ſome Diſtance from this ſame *Axis*, are but faintly and obſcurely perceived; yet we are ſeldom ſenſible of this Defect; and, in viewing Bodies that are pretty large, we are

are apt to imagine, that we ſee at the ſame time all their Parts equally diſtinct and clear. But this is a vulgar Error, and we are led into it from the quick and almoſt continual Motion of the Eye, whereby it is ſucceſſively directed to all the Points of the Object in an Inſtant of Time; for it is certain, that the Idea of Objects which we receive by Sight, do not preſently periſh, but are of a laſting Nature, as appears from what happens when a burning Coal of Fire is nimbly moved round in a Circle with Gyrations continually repeated; which makes the whole Circle appear like Fire, becauſe the Senſation of the Coal, in the ſeveral Places of that Circle, remains impreſſed on the *Senſorium*, until the Coal return again to the ſame Place; for the Motions excited in the Bottom of the Eye by Light, and thence propagated to the *Senſorium*, are of a laſting, and conſequently of a vibrating Nature; and therefore if our Eye takes no longer Time to direct itſelf ſucceſſively to all the Parts of an Object, than what the Coal of Fire takes to go round, the Mind will diſtinctly perceive all thoſe Parts, without being ſenſible of any Defect or Inſenſibility in any Part of the *Retina*, becauſe the Idea of one Part continues, till, by the Motion of the Eye, the Image of the other Parts be ſucceſſively received upon the ſame moſt ſenſible

Part

Part of the *Retina*; and this is one Reaſon why the Globe of the Eye moves ſo quickly, and that its Muſcles have ſuch a Quantity of Nerves to perform their Motions.

§ 9. There is yet another Defect in the *Retina*; of which alſo we are ſeldom ſenſible; and that is, that it is inſenſible in that Part where the optic Nerves enter our Eyes.

We have already noticed, that our optic Nerves never enter our Eyes exactly at their *Axis*, that is, at the Place where the Image of any little Object to which our Eye is directed does fall, but a little on the Inſide towards our Noſe; and therefore, to be aſſured that that Part of the *Retina* which anſwers to the Extremity of the Nerve is inſenſible, we muſt find out ſome Method of making the Image of an Object fall upon it. The famous M. MARIOTTE, that great Ornament of the *French* Academy, and diligent Promoter of Knowledge, was the firſt who ever thought of this Matter. His Experiment is as follows:

Take two ſmall Pieces of Paper, of a round Figure, and about three or four Inches in Diameter, and fix them on a dark Wall, about the Height of your Eye, and about two Feet diſtant from each other; then having ſhut the Left-eye, place yourſelf exactly oppoſite to the Paper on the Left-hand, and keeping your

your Right-eye fixed ſtedfaſtly upon it, draw back, little by little, and you ſhall obſerve, that, when you have retired about nine Feet, the Paper on the Right-hand will intirely diſappear, and you will be almoſt tempted to believe, that it has fallen down, or that it has been otherwiſe dextrouſly taken away without your Knowledge. And the ſame Experiment ſucceeds in like manner, when made with the Left-eye, the right one being ſhut.

This is truly a very beautiful and ſurpriſing Experiment; and it plainly proves, that there is a Part of our *Retina* towards the Inſide of the optic *Axis* intirely inſenſible. And this Part is found to anſwer pretty exactly to the little Circle which the Extremity of the optic Nerve makes where it enters the Eye: For it is an agreed Point, that, in this Experiment, moſt Men loſe Sight of an intire Circle of white Paper, whoſe Diameter is about the ninth or tenth Part of its Diſtance from the Eye; and ſeeing the viſual Triangle, whoſe Baſe is the Diameter of this Circle, and its *Vertex* the Centre of the Eye, is ſimilar to the Triangle whoſe Baſe is the Diameter of the Picture of that little Circle upon the *Retina*, and its *Vertex* the ſame Centre, where the extreme Rays are ſuppoſed to interſect each other; it follows, that this *Baſis* or the Diameter of the

Picture, will alſo be about the ninth or tenth Part of its Diſtance from the ſaid Centre of the Eye: But this Diſtance from the Centre of the Eye is about ſix Lines, the ninth Part of which is two thirds of a Line, which anſwers pretty exactly to the Diameter of the optic Nerve: So that, the Picture of the white Paper will cover the whole Baſe of the optic Nerve, which muſt therefore be totally inſenſible of Light.

I have here, agreeably to moſt of our optical Writers, ſuppoſed, that the viſual Angle has its *Vertex* in the Centre of the Eye: But, if this *Vertex* ſhould be ſuppoſed not in the Centre of the Eye, but in the Centre of the *Cornea*, which Centre, according to PETIT's Meaſures, lies between the Back-part of the Cryſtalline and the Centre of the Eye, the Picture on the *Retina* will be yet larger, and of conſequence muſt fully cover, if not ſomewhat exceed the *Baſis* of the optic Nerve.

§ 10. This famous Experiment of Mr. MARIOTTE did at firſt very much ſurpriſe both Phyſicians and Philoſophers, none of whom had ever before dreamed of any ſuch Defect in the Sight; but they were all preſently convinced of it, after they had made the Experiment; and as the whole Secret of this Experiment conſiſts in making the Picture of an Object fall exactly upon the Entry of the

the optic Nerve, the learned Mr. PICARD deviſed a way by which an Object becomes inviſible when both Eyes are kept open, becauſe the Image is made to fall upon both optic Nerves at the ſame time. His Method of doing this is as follows:

Faſten againſt a Wall a round white Paper, of the Bigneſs of an Inch or two, and, on the Sides of this Paper, put two Marks, one on the right, the other on the left, each about two Feet diſtant from the Paper, and ſomewhat higher; then place yourſelf directly before the Paper, at the Diſtance of nine or ten Feet, and put the End of your Finger over againſt both of your Eyes; ſo as it may hide from the Right-eye the left Mark, and from the Left-eye the right Mark: If you remain firm in that Poſture, and look ſteadily with both Eyes on the end of your Finger, the Paper, which is not at all covered thereby, will totally diſappear; which is the more ſurpriſing, becauſe, without this particular Encounter with the optic Nerves, where no Viſion is made, the Paper will appear double, as you will find when the Finger is not rightly placed.

This Experiment ſerves to confirm what Mr. MARIOTTE firſt diſcovered concerning the Inſenſibility of the *Retina*, where the optic Nerves enter; but becauſe it is ſomewhat difficult to perform, by reaſon of the great Effort

Effort which must be made for to keep both Eyes fixed upon the Finger, which is only about four Inches distant from the Eyes, I shall here give you another Method, whereby an Object may be rendered invisible when both Eyes are open, which is much more easy, and is no less surprising.

Fix upon a dark Wall two little Circles of white Paper, at the same Height, and about three Feet Distance from each other; and, having placed yourself directly opposite to these Papers at the Distance of twelve or thirteen Feet, hold your Finger about eight Inches before your Eyes, so as it may cover from your Right-eye the Paper towards the Left-hand, and from the Left-eye, the Paper towards the Right-hand; then if you look to your Finger attentively with both Eyes, you shall lose the Sight of both Papers intirely. This proceeds, as is easy to see, from the Direction of the Eyes, and Situation of the Finger; for each of the Eyes receives the Image of one of the Objects on that insensible Part of the *Retina* where the optic Nerve enters, and the Finger does cover from it the other.

The same Experiment may be made with two lighted Candles, observing always the same Distance; for, if they be placed farther from each other, you must also in proportion retire to a greater Distance, otherwise the Image of the

the Object will not fall on that insensible Part of the *Retina;* as for Instance, if the Distance of the Candles be 6 Feet, you must retire to 25 Feet Distance, and at other Distances in proportion: But the Finger must always abide nearly in the same Situation; for if it be placed at a Foot, or any greater Distance from the Eyes, there will then appear four Candles, in place of two, as is easy to understand from what has been before explained.

§ 11. Now, tho' it is certain, from the above Experiments, that our *Retina* is insensible towards the Inside of the optic *Axis*, where the optic Nerves enter the Globe; yet we are never sensible of this Defect in our Sight when both Eyes are open, because it is impossible that any Object, or Part of an Object, can be so situated, as to have its Picture on the Inside of the optic *Axis* in both Eyes; and therefore what is lost to one Eye, is always visible by the other. But had Nature made our optic Nerves to enter our Eyes in the Middle, directly opposite to the Pupil, then the Middle Part of all Objects would have been invisible, because its Picture would have fallen upon the insensible Part of the *Retina* in both Eyes, which would have been a prodigious and unsupportable Defect in our Sight. To prevent which, provident Nature has wisely inserted

ſerted our optic Nerves, not in the optic *Axis*, but on the Inſide towards the Noſe.

§ 12. But we are not only inſenſible of this Defect in our Sight when both Eyes are open, but, which is very ſurpriſing, in looking at Objects of an uniform Colour with one Eye, the other being ſhut, we are not ſenſible of any Defect or dark round Spot, anſwering to the inſenſible Part of the *Retina*. This becomes very evident, when, in the Manner above noticed, one loſes Sight of a round black Paper faſtened againſt a white Ground; for no Defect or Obſcurity is to be ſeen in the Place of the black Paper, but the Ground appears white over all its Extent, the ſame that it does when the black Paper is taken away from before it: The Reaſon of which ſeems to be, that this Defect of Senſation having been conſtantly ſupplied by the other Eye, is now ſupplied by the Imagination only.

§ 13. This Inſenſibility which MARIOTTE firſt diſcovered in the *Retinæ*, where the optic Nerves enter the Globe, made him ſuſpect that all Authors were miſtaken in thinking the *Retina* the immediate Organ of Sight; and, after he had fully weighed the Matter, he gave in a Paper to the Royal Academy, which was read at one of their Meetings, wherein he endeavoured to prove, by ſeveral ingenious Arguments,

guments, that the principal Organ of Vision is not the *Retina*, as was commonly believed, but that Membrane lying behind it called *Choroides*. This new and singular Opinion gave Occasion to several Epistles betwixt MARIOTTE, on the one Hand, in favours of the *Choroides*, and M. PECQUET and PERRAULT, on the other, in favours of the *Retina*; wherein the Argument on both Sides was so dextrously managed, that it is very difficult for one to determine himself which Opinion he ought to embrace.

§ 14. Mr. MARIOTTE's Arguments are in Substance as follows:

1*mo*, The *Retina* is transparent, and consequently, like all other transparent Bodies, such as Air, Water, *&c.* it can receive but a very faint Impression from the Rays of Light; but, on the contrary, opaque and black Bodies, such as the *Choroides*, receive a stronger and more lively Impression, and therefore must be better qualified for being the principal Organ of Sight.

To this PECQUET answers, that it is certain, that the *Retina* has some Degree of Transparency, by means of which the Colour of the *Choroides* may be seen thro' it; but this Transparency is very far inferior to that of Air or Water, and is much the same with that of oiled Paper; for if the *Sclerotis* and *Choroides* be taken

taken away from a freſh Eye, and the *Retina* be left extended on the vitreous Humour, one ſhall not be able to ſee well thro' this Membrane, becauſe of its Opacity; and if the *Retina* be immerſed in Water, you ſhall obſerve it altogether white, and almoſt without Tranſparency: From which he concludes, that this Opacity in the *Retina* is ſufficient to ſtop the Rays as much as is needful for diſtinct Viſion, and to hinder them from reaching the *Choroides* in that Quantity which the painting a diſtinct Image of the Object thereon would require; for if it be ſuppoſed neceſſary for Viſion, that the Light ſhould paſs to the *Choroides*, the Opacity of the *Retina* would be as hurtful to the Sight, as if the *Cornea*, Cryſtalline, or other Humours, had been tainted with the ſame Opacity, which Nature has always made tranſparent for tranſmitting the Rays to the Organ of Sight.

And as to the Blackneſs of the *Choroides* which MARIOTTE pretends to be neceſſary for Viſion, the ſame Author anſwers, that tho' this Membrane in Man, Birds, and ſome other Creatures, be black, yet, in the Eyes of other Animals, ſuch as the Lyon, Camel, Bear, Ox, Dear, Sheep, Dog, Cat, *&c.* it is never black, but of ſome other bright and reſplendent Colour; and Fiſh have commonly the *Choroides* covered with a Colour as bright and ſhining

ſhining as the fineſt oriental Pearl; theſe Colours form upon the Surface of the *Choroides* a Sort of *Tapetum* or Carpet, which of Neceſſity muſt intercept the Rays, and hinder them from paſſing to the *Choroides* for painting thereon the Images of Objects: From all which he concludes, that tho' black Bodies receive the ſtrongeſt Impreſſions from Light, yet from thence it does not follow, that the *Choroides* is the principal and immediate Organ of Sight; becauſe, 1*ſt*, It is not always black, but, in divers Animals, of divers Colours; and, 2*dly*, becauſe the Opacity of the *Retina* intercepts the Light, and hinders it from paſſing to the *Choroides* in that Quantity which is needful for Viſion.

To this Mr. MARIOTTE replies, that tho' the *Retina* may have ſome little Opacity and Whiteneſs, yet it is not ſuch as can hinder the Light from paſſing to the *Choroides* in that Quantity which is neceſſary for Viſion, but only ſuch as may be neceſſary for ſoftening and diminiſhing its too great Strength and Vivacity, which might hurt the *Choroides* when Objects are too bright and luminous; in like Manner as the inſenſible *Epidermis*, or Scarf-ſkin, which is extended over all the organ of Touch, hinders that it be not hurt by the Bodies which we touch, or by the Exceſs of Cold and Heat to which we are often expoſed.

And as to what PECQUET alledges, That, having taken away the *Sclerotis* and *Choroides* from an Eye, and left the *Retina* extended over the vitreous Humour, this Membrane is ſo opaque, that Objects cannot be ſeen diſtinctly thro' it; MARIOTTE will not allow this to be a good Argument for proving the Opacity of the *Retina*; and that becauſe there may be a great Difference betwixt the *Retina* of a dead Animal expoſed to Air, and that of a living Animal exactly incloſed betwixt the vitreous Humour and *Choroides*. Different Diſpoſitions change the Qualities of Things; Paper, when wetted, is tranſparent, but ſoon becomes opaque, when expoſed to Air, by the Evaporation of the Water with which it was moiſtened: Fat, which is tranſparent when melted, grows opaque when cold: The *Cornea* of an Eye being held ſome Hours in a hot Air, becomes gradually leſs and leſs tranſparent, and at laſt altogether opaque: The little Cryſtalline which Fiſh have in the Middle of the great one, when the Animal is alive, is as tranſparent as the other Humours of the Eye; but, two or three Days after Death, it becomes white and opaque, tho' it remain ſhut up in the Eye, and the external Cryſtalline retain its former Tranſparency. It is not therefore a good Argument to prove the Opacity

city of the *Retina*, that it is ſomewhat opaque in dead Animals.

The ſame Author obſerves, that Mr. PECQUET's ſecond Argument for proving the Opacity of the *Retina*, is alſo deceitful; For tho' it appear white when immerſed in Water, yet it is not ſo naturally; for the Membrane covering the vitreous Humour, tho' naturally tranſparent, yet, when it is put amongſt Water, it alſo appears whitiſh and opaque, like a Cob-web; and therefore, ſays he, it is not a good Method for diſcovering if the *Retina* be opaque in a living Animal, to plunge it amongſt Water: and no Conſequence can be drawn from any Experiments made upon the *Retina* after it has been expoſed to Air, to prove that it is naturally opaque when the Animal is alive; for the Cryſtalline itſelf becomes a little muddy in Water; and if it remain therein for any Time, or if it be expoſed to Froſt, it turns white and opaque like Snow.

To know therefore the natural State of the *Retina*, and whether the Light of Objects does paſs almoſt intirely to the *Choroides*, or if it be almoſt all ſtopt by the *Retina*, it is neceſſary to make ſome other Experiments; ſuch as the following:

Take the Eye of an Ox new killed, while it is hot, and cut it in two tranſverſly, in ſuch

ſuch a manner as a good Part of the vitreous Humour may remain extended upon the *Retina*, then you ſhall ſee diſtinctly the Colours of the *Choroides*, the Baſe of the optic Nerve, the Trunk of the little Veſſels that proceed from thence, and their Diſpoſition thro' the Thickneſs of the *Retina*, with ſo much Perſpicuity, that you cannot even diſcern whether there be a *Retina* beyond the vitreous Humour or not: Whence it follows, that the Light which Objects ſend to the *Choroides* is more than ſufficient to produce Viſion therein; ſince, after it is reflected from it, and has repaſſed thro' the *Retina* and vitreous Humour of the Oxe's Eye, it is yet ſtrong enough for making us ſee the *Choroides* diſtinctly.

The Tranſparency of the *Retina* will alſo be evident from this other Experiment: Place by Night a lighted Candle near your Eyes, and Cauſe a Dog, diſtant from the Candle eight or ten Paces, to look at you, and you ſhall ſee in his Eyes a bright ſhining Light, which can proceed from nothing but the Reflection of the Light of the Candle, whoſe Image is painted on the *Choroides* of the Dog, which having much Whiteneſs and Luſtre, cauſes this ſtrong Reflection: For if it proceeded from the Cryſtalline or *Retina*, or the far Surface of the vitreous Humour, the ſame Appearance would be ſeen in the

Eyes

Eyes of Men, Birds, and other Animals; which never happens, becauſe their *Choroides* is black, and conſequently unfit for reflecting the Light which falls on it. It is therefore manifeſt, by this Experiment, that the Rays do paſs with much Force, as far as the *Choroides*; and that the *Retina* receives but a very faint Impreſſion from them, becauſe of its Tranſparency. The like Experiment may be made with ſeveral other Creatures, and particularly with Cats, in whoſe Eyes this Light appears blueiſh; which ſhews that it proceeds from their *Choroides* which hath much of this Colour.

But, that this Experiment may be the better underſtood, I ſhall explain the Reaſon of it more particularly; it is this: The little Image of the Candle which is made on the *Choroides*, where the Cryſtalline and the other refracting Humours have their *Focus*, ſends back the Rays thro' the Humours, which will therefore be again brought together, and re-united in the Place of the Candle; and the Spectator's Eyes being near the Candle, muſt of conſequence ſee the Cryſtalline of the Dog greatly illuminated, juſt as when one looks at a Candle thro' a convex *Lens* or Spectacle-Glaſs, having his Eye placed in the *Focus*, where the Image of the Candle is made; for the Glaſs then appears bright

and

and ſhining, like ſo much Fire, becauſe the Candle is then ſeen in the Glaſs; as Opticians know.

This may ſtill be further illuſtrated, by placing a round Glaſs Decanter full of Water, about eighth or ten Feet from a Candle, and putting a white Paper behind the Decanter, about the Diſtance of Half its Diameter, ſo as it may receive the Image of the Candle in the *Focus* of the Rays; for thoſe who have their Eyes near the Candle, will ſee the Decanter full of Light, which will vaniſh when the Paper is moved to a greater or leſſer Diſtance from the Decanter; and if you ſhall put a lighted Wax Taper or *Bougie* in place of the Paper, the Eye being placed in the Place of the Candle after it is taken away, ſhall ſee the Decanter yet more bright and luminous than before: Whence it is evident, that the Light which appears in the Dog's Eye proceeds from the like Cauſe. And, to confirm this ſtill further, let the Candle be placed to a-ſide, ſo as it may illuminate your Face ſtrongly, while, at the ſame time, it does not ſhine upon the Dog; for here alſo you ſhall ſee much Light in his Eyes: But if you ſhade your Face from the Candle, this Light will diſappear; which is a convincing Proof, that it proceeds from the Image of your Face in his

his Eyes, and that it is upon the *Choroides* that this Image is painted.

I have been the more particular in explaining this Experiment, as it may ſerve to account for the Radiation of the Eyes of Cats and other nocturnal Animal, which many have without Cauſe deduced from an inherent Light in their Eyes. But I muſt proceed:

As to PECQUET's other Objection, taken from the different Colours of the *Choroides* in different Animals, MARIOTTE acknowledges, that, in ſeveral Creatures, it is not black, but of ſome other bright Colour; and he does not affirm, that Blackneſs in the *Choroides* is abſolutely neceſſary for Viſion, but only for rendering Viſion more ſtrong and lively. His Doctrine is this: The *Retina* being tranſparent, can receive but a very faint Impreſſion from the Light: But the *Choroides*, like all other opaque Bodies, muſt receive a ſtronger Impreſſion; and if it be black, the Impreſſion will be yet ſtronger than when it is of any other Colour; for black Bodies grow hotter in the Sun, and take Fire ſooner than Bodies of other Colours, and eſpecially white Ones; and therefore the Light acts more upon them. And this is the Reaſon why Men and Birds ſee better and more diſtinctly than moſt other Animals; for their *Choroides* being black, and

by

by conſequence very ſenſible of Light, they contract their Pupil much, which makes the Rays which paſs there, from each Point of the Object, to be all very near the *Axis* of the Cryſtalline, and to re-unite more exactly in a Point than in the Eyes of moſt other Animals which have their *Choroides* white towards the *Axis* of the Eye, and by conſequence leſs ſenſible of Light, but who, in Recompence, can very much dilate the Pupil of their Eyes, when they ſtand in need of great Light; but then their Sight is not ſo diſtinct, becauſe the Rays which fall towards the Edge of the Cryſtalline do interſect the *Axis* too near the Cryſtalline in their Refractions.

2*do*, Mr. MARIOTTE's ſecond Argument againſt the *Retina*'s being the immediate Organ of Viſion, is, that it is not compoſed of Fibres, but that it is only a ſoft Glue or *Mucus*, which does not communicate with the Brain. But the *Choroides*, which is a Production of the *Pia Mater*, covers the Optic Nerve beyond the Eye, and accompanies the Nerve thro' its whole Courſe to its Origin in the Brain.

But this Argument has but little Weight; for all Anatomiſts agree with PECQUET in making the *Retina* nothing but a Continuation of the medullary Fibres of the optic Nerve, which,

which, tho' becauſe of their Smallneſs and Delicacy, which was neceſſary that they might be the more ſuſceptible of the Impreſſions of Light, they ſeem to compoſe a ſort of Glue or *Mucus*; yet this Glue or *Mucus*, when the *Retina* is put amongſt Water, appears plainly to be a Continuation of the medullary Subſtance of the Nerve. It cannot indeed be denied, that the *Choroides* does likewiſe terminate in the Brain, and therefore it muſt be allowed that both the one and the other are upon that Account equally qualified for conveying the Impreſſions of Light to the *Senſorium*; and therefore, to determine this Queſtion, we muſt have Recourſe to other Arguments than thoſe taken from the want of Communication betwixt either the *Choroides* or *Retina* and the Brain.

3*tio*, Another Argument of MARIOTTE's in favour of the *Choroides*, is, That ſince the *Retina* is tranſparent, and about half a Line thick, it is impoſſible it can be the Organ of Sight, becauſe of its Thickneſs: For diſtinct Viſion conſiſts in the Union of the Rays which come from the ſeveral Points of the Object in ſo many correſponding Points in the Organ of Sight; and therefore, if the Rays be united at a Point in its Surface next the vitreous Humour, they will interſect each other, and Fall on different Points in its other Surface,

next the *Choroides;* and if they be united in a Point in this Surface, they muſt have paſſed the other Surface in different Points, and if they be united any where betwixt theſe two Surfaces, they muſt fall on different Points in both the Surfaces: And thus Viſion will be rendered confuſed, in whatever Part of the *Retina* the Rays be conceived to unite; but the *Choroides* being very opaque, may receive the Rays which come from each Point of the Object at as many correſponding Points in its Surface; which, becauſe of its Opacity, cannot be penetrated thereby, and conſequently it muſt be well qualified for diſtinct Viſion.

To this Mr. PECQUET Anſwers, That tho' diſtinct Viſion conſiſts in the Union of the Rays which come from the ſeveral Points of the Object, at ſo many correſponding Points in the Organ of Sight; yet theſe Points are not to be underſtood as mathematical Points, without Magnitude, but as phyſical Ones, which may occupy a Space equal to the ſmall Thickneſs of the *Retina*, without cauſing any Confuſion; for the *Retina*, he ſays, in Man is ſcarce thicker than ordinary Paper, and in Oxen, Horſe, Deer, Lyons, Boars, Swine, Sheep, Dogs, and other large Animals, which he has examined, it never exceeds three or four Leaves of Paper, which is leſs than the fourth Part of a Line.

But

But MARIOTTE is not satisfied with this Answer. He indeed acknowledges, that the Point of the Organ of Sight, in which the Rays are united by Refraction, is a physical Point: But then he contends, and that with good Reason, that it is much smaller than any that can be perceived by Sight; for the Image of the Object painted on the Organ of Sight, being vastly smaller than the Object itself, every Point of that Picture must also be much smaller than the visible Point of the Object which it represents; and therefore, since we can see distinctly very small Objects, such as the minute Ramifications of the Arteries in the *Retina*, whose Diameter does not exceed the 8th Part of the Thickness of that Membrane, its Image on the *Retina* must be 25, or 30 times smaller; for the Magnitude of the Object is to the Magnitude of the Picture, as the Distance of the Object from the Centre of the Eye, is to the Distance of that Centre from the Organ of Vision; and consequently, the Thickness of the *Retina*, tho' it were less than the 4th Part of a Line, is by no Means proper for such a Smallness; but must produce a Confusion in the Sight in the Manner above explained.

4*to*, Mr. MARIOTTE's last Argument in favour of the *Choroides*, is taken from that Insensibility of the Organ of Sight where the optic

optic Nerves enter the Globe; for if Viſion were made in the *Retina*, it ſhould be made wherever the *Retina* is; and ſince the *Retina* covers the whole Nerve, as well as the reſt of the Bottom of the Eye, there appears no Reaſon why there ſhould be no Viſion in the Place of the optic Nerve; but, on the contrary, if it be in the *Choroides* that Viſion is made, it is evident, that the Reaſon why there is none in the Nerve, is, that the *Choroides* parts from its Edge and covers not the Extremity thereof, as it does the reſt of the Bottom of the Eye.

This is the ſtrongeſt of all MARIOTTE's Arguments; neither is it eaſy, ſuppoſing the *Retina* to be the Organ of Sight, to give a ſufficient Reaſon for its being inſenſible where the optic Nerve enters the Eye. Mr. PECQUET has indeed propoſed ſeveral plauſible Conjectures; but they are ſuch as do not ſeem ſufficient to overturn MARIOTTE's Opinion.

His firſt Hypotheſis is, that the nervous Fibres next the Centre of the Nerve, do all terminate exactly at its Circumference, after having covered its Extremity equally in expanding themſelves every way, like Rays drawn from the Centre to the Circumference. So that, according to him, none of the nervous Fibres terminate in the Extremity of the Nerve,

Nerve, till they have proceeded as far as its Circumference; and that the other Fibres of the Nerve, more remote from its Centre, do terminate in the *Retina*, ſtill further and further from the Circumference of the Nerve, according as they are at a greater or leſſer Diſtance from its Centre; and thus the whole outward Suface of the *Retina* is compoſed of the Extremities of the Fibres of the Nerve, excepting only that Part of it where the Nerve enters, in which none of theſe Fibres terminate. This being ſuppoſed, he ſuppoſes further, that there is no Viſion but when the Rays of Light fall on the Extremity of the nervous Fibres, and thence accounts for the Inſenſibility of the *Retina* where the optic Nerves enter.

But, ſuppoſing it were neceſſary for Viſion, that the Rays ſhould fall on the Extremities of the nervous Fibres, of which however there is no Proof; yet it is not to be imagined, that Nature would have thus diſpoſed the Fibres of the Nerve, ſo as none of them ſhould terminate in the *Retina* at the Extremity of the Nerve; ſince, as MARIOTTE obſerves, a ſimple direct Continuation of theſe Fibres to the anterior Surface of the *Retina* would have been ſufficient for that Purpoſe: Whereas, according to PECQUET's Hypotheſis, they are carried ſtill further, as far as the Circumference of the Nerve, before any of them terminate; which is

is to make Nature do ſomething in vain, or rather to do ſomething for no other Reaſon, than to produce a Defect in the Sight. This Hypotheſis therefore ſeems to be altogether improbable.

His ſecond Hypotheſis is, That the nervous Fibres of which the *Retina* is compoſed, do all terminate at the Extremity of this Membrane, in like manner as the Fibres of a Plant terminate in the Extremity of its Flower; from which he concludes, that there muſt be a ſmall Cavity formed in the Centre of the *Retina*, from which Centre theſe Fibres begin to expand themſelves; and that the Rays of Light which fall on this Cavity do ſtrike its Fibres after a different Manner from what happens in the other ſenſible Parts of the *Retina*. The ſenſible Parts of the *Retina*, ſays he, receive the Rays perpendicularly; but this Part, becauſe of its Hollowneſs, muſt receive them obliquely, ſo that its Fibres will not be ſufficiently agitated for cauſing Viſion.

But this Hypotheſis is far from ſatisfying; for Experience ſhews, that where the optic Nerve enters, there is never any ſuch Cavity formed as PECQUET ſuppoſes; and beſides, ſuppoſing it were otherwiſe, yet it does not follow that this Cavity would be inſenſible, becauſe of the Obliquity of the Rays which fall thereon; for, as MARIOTTE obſerves, it is not neceſſary for Viſion, that the Rays fall directly

directly upon the Organ of Sight, as PECQUET ſuppoſes; it is ſufficient that all the Rays which come from a Point of the Object be re-united in a Point on the Organ: And it is eaſy to ſee, that of all the Rays that are made to converge and meet at a Point in the Organ, whether it be ſuppoſed the *Retina* or *Choroides*, there is only one that can fall on it directly; for, as the Rays of Light which come from the Object, form a Cone, whoſe *Baſis* is the Pupil, and *Apex* a Point in the Object; ſo theſe ſame Rays do within the Eye form another Cone whoſe *Baſis* is alſo in the Pupil, and whoſe *Apex* is in that Point of the Organ to which they converge; and therefore, if the middle Ray which paſſes thro' the Centre of the Pupil be ſuppoſed to fall perpendicularly upon the Organ of Sight, as it certainly does, all the other Rays, which paſs thro' the other Parts of the Pupil, muſt fall obliquely upon that Point of the Organ, and yet this Obliquity does not occaſion any Defect in the Sight; from which it follows, that the *Retina* is not rendered inſenſible, where the optic Nerves enter, from the Obliquity of the Rays that fall thereon.

PECQUET himſelf appears not to be ſatisfied with theſe Reaſons; and therefore propoſes a third, which, tho' the moſt plauſible of all, yet when duly conſidered, does likewiſe

wiſe appear inſufficient for over-turning MARIOTTE's Hypotheſis. It is as follows:

All Anatomiſts have obſerved, that with the optic Nerve, there enters the Eye ſome little Trunks of Blood-Veſſels, which are afterwards divided into minute capillary Ramifications, which are diſtributed thro' the *Retina*. Now (ſays he) the Inſenſibility of the *Retina* where the optic Nerve enters, is no Argument againſt its being thought the immediate Organ of Sight, becauſe in that Place the Rays of Light do not fall upon its nervous Fibres, but upon the Blood-Veſſels, which are large enough for occaſioning that Defect in our Sight.

To this MARIOTTE anſwers, That it is certain, that ſome Veſſels enter the Eye with the Nerve, but, that they are very ſmall, and that it is very hard to diſcern the little Holes thro' which they paſs, when the Nerve is cut off above its Inſertion into the Eye. He alſo obſerves, that theſe Veſſels do frequently pierce the *Baſis* of the Nerve by two diſtinct little Holes, the Diameter of each of which does not take up above an eight Part of the Diameter of the inſenſible *Baſis* of the Nerve; and thence concludes, that that Part of the *Retina* anſwering to the whole *Baſis* of the Nerve, could never be rendered inſenſible by ſuch ſmall Veſſels, which could only make us loſe Sight of a Paper of two Inches Diameter,

ter, at moſt, at ten Feet Diſtance: and that ſometimes, *viz.* when there are two little Veſſels in that Place, as often happens, we ought to loſe Sight of two ſmall Papers of a Bigneſs anſwerable to the two little Veſſels upon which their Image falls, and at the ſame time ſee diſtinctly the whole Space betwixt them; which is contrary to Experience; for the Default of Viſion is always continued, and anſwers to the whole *Baſis* of the Nerve. From all which he concludes, that the *Choroides* is the immediate Organ of Sight; and that this Defect thereof where the optic Nerves enter, is occaſioned from the want of the *Choroides* in that Place, and not from the Blood-Veſſels, as PECQUET alledges.

§ 15. Having given you the Subſtance, of what paſſed betwixt MARIOTTE and PECQUET, with regard to the principal Organ of Sight, I might now examine the Cauſes which Mr. PERRAULT, in Support of the *Retina*, aſſigns for that Defect of Sight, where the optic Nerves enter; but I think it unneceſſary, becauſe they are only Conjectures; and ſuch Conjectures too, that ſuppoſing them true, yet they do not appear ſufficient to overturn MARIOTTE's Opinion. And this appears, not only from the Epiſtles that paſſed betwixt them, to which the curious may have Recourſe, but alſo from the Authority of *M. de la*

HIRE, one of the moſt learned Members of the *French* Academy, and an excellent Judge of theſe Matters, who therefore, in the Year 1694, after ſhewing his Diſſatisfaction with all that PECQUET and PERRAULT had ſaid, did account for that Inſenſibility of the *Retina* at the *Baſis* of the Nerve more ingeniouſly, than either PECQUET or PERRAULT, or any other that went before him.

His Opinion is, That this Defect in the Sight, where the optic Nerves enter, cannot be attributed to Blood-Veſſels, or to any thing elſe but the Want of the *Choroides* in that Place; but yet he thinks, that the *Choroides* is not to be eſteemed the principal Organ of Sight; for he thinks it ridiculous to ſearch for the Organ of any Senſe any where, but in the Nerve; and the *Retina* being an Expanſion of the nervous Fibres which are diſtributed thro' all the Bottom of the Eye, he with very good Reaſon, looks on it as the immediate Organ of Sight; but then he thinks that this Organ does not receive that Impreſſion which is neceſſary for producing Viſion immediately from the Rays themſelves, but that they paſs thro' the tranſparent *Retina* to the *Choroides*, which being opaque and frequently black, is excellently qualified for being agitated by the Rays of Light; and that theſe Agitations excited in the *Choroides* are communicated to the

the *Retina* which it toucheth, and from it are carried to the common Senſory, by Means of the medullary Subſtance of the Nerve, of whoſe Fibres the *Retina* is an Expanſion.

This is indeed a very beautiful and ingenious Opinion, and does excellently well account for that Defect which MARIOTTE firſt obſerved in the Sight where the optic Nerves enter: For, ſuppoſing the *Retina* the immediate Organ of Sight, and that it is neceſſary that the *Choroides* ſhould act the Part of an intermediate Organ, and receive all the different Impreſſions of Light for to tranſmit them to the *Retina*, and to render them ſenſible to it, by a Modification proper for that Effect; it is eaſy to ſee, that the *Retina* cannot receive theſe Impreſſions which are neceſſary for Viſion, where the *Choroides* is wanting; and that therefore there muſt be a Defect in the Sight at that Place where the optic Nerves enter the Globe.

And this Opinion appears ſtill the more probable, from what every body knows to happen in the Ear; for the ſpiral Lamell has a proper Diſpoſition to receive the Tremors of the Air, and to communicate them to the Ramifications of the Auditory Nerve expanded upon it, for exciting in the Mind the Idea of Sound: And the Caſe is the ſame in the other Senſes, as *M. de* VERNEY has well obſerved,

observed, in the 96th Page of his elegant Treatise *de l'Organe de l'Ouie*; for the Nerves are of a Nature too tender and delicate for to be exposed naked to the Action of external Bodies; and therefore it was necessary that the Membranes which cover the Nerves, and which are as a middle Organ, should receive the proper Impressions for to communicate them to the Nerves, with that Disposition and Modification which is proper for the Sensation.

§ 16. These Reasons appeared to me so very strong and convincing, that I very readily went into *de la* HIRE's Opinion. But I afterwards met with two anatomical Observations, made by the Members of the Royal Academy, which intirely destroys this Hypothesis; but, by good luck, at the same time, they finally determine the Question before us, Whether it be the *Retina* or *Choroides* that is the immediate Organ of Sight?

These Observations are, the one upon the Sea Calf, and the other upon the Porcupine; both which were found to have their optic Nerves inserted in the *Axis* of the Eye directly opposite to the Pupil. (See their Natural History of Animals.) Dr. WILLIS, in his *Anima Brutorum*, tells us, that the same thing obtains in Dogs; and Dr. BRIGGS, in his *Ophthalmographia*, says, that the Nerve enters the Globe

Globe in the Middle oppoſite to the Pupil, not only in Dogs, but alſo in Cats, and all the other ſagacious Animals, without Exception; but, not being appriſed of the Conſequence of ſuch Obſervations, it ſeems they were at little Pains in making them accurate, as appears from what they tell us in the ſame Place, that the optic Nerve does alſo enter the Eye in its *Axis* in Men; which is certainly a Miſtake, tho' it is not ſo much to a-ſide as in Oxen, Sheep, Swine, and the greateſt Part of Birds and Fiſhes. But what theſe Gentlemen of the Academy of Sciences have obſerved to us with regard to the Inſertion of theſe Nerves in the Porcupine and Sea-Calf, may be more ſafely relied on, becauſe they were at Pains to examine it exactly, knowing the Conſequence of ſuch Obſervations, in overturning MARIOTTE's Hypotheſis; which they do moſt effectually; as every one muſt ſee, without my needing to ſay any thing further upon it.

Neither is it poſſible, that this Defect in our Sight where the optic Nerves enter, can be owing to the Want of the *Choroides* in that Place, which, according to *de la* HIRE, ought to receive the Impreſſion from the Rays of Light, and communicate it to the *Retina*, with that Diſpoſition and Modification which is proper for Viſion; for, were this

true,

true, then, in theſe Creatures which have the optic Nerves ſituated in the *Axis* of the Eye, and which, by conſequence, do directly receive on the Extremity of the Nerve the viſual Species, all Objects would become inviſible to which their Eyes are turned, becauſe the *Choroides* is wanting in that Place where the Image falls; which being contrary to Experience, it follows, that ſome other Cauſe muſt be aſſigned for this Defect in our Sight, where the optic Nerve enters the Globe, than the Want of the *Choroides*.

§ 17. In order to find ſomething probable in ſo difficult a Matter, we muſt conſider, that Viſion conſiſts in Impreſſions made on the Organ of Sight, which are infinitely more ſlight and delicate than the Impreſſions made upon the other Organs of Senſe; and therefore, that the Organ might be ſuſceptible of theſe weak Impreſſions, it was neceſſary that it ſhould be endowed with a Subſtance exquiſitely delicate and tender: And this may be the Reaſon, why the *Retina* is made ſo ſoft and tender, that it appears like the medullary Part of the Nerve diſſolved into a Sort of ſoft Glue, or *Mucus*. Now, it is very probable that this Defect in our Sight where the optic Nerves enter the Globe, proceeds from the Hardneſs and Calloſity of the *Retina* in that Place, which has not as yet acquired

that

that Softneſs and Delicacy that is neceſſary for receiving ſo ſlight Impreſſions as thoſe of the Rays of Light; for the *Retina* is always a great deal more ſoft and tender than the medullary Part of the Nerve of which it is formed, excepting where it covers the *Baſis* of the Nerve, which ſtill retains ſomething of that Firmneſs which it had in the Nerve, by which it is rendered unfit for being ſufficiently agitated by the faint Impreſſions of Light. And this we take to be the Reaſon, why that Part of our *Retina* is inſenſible where the optic Nerve enters.

And this Conjecture is rendered ſtill the more probable, from what PECQUET tells us, that bright and luminous Objects, ſuch as a bright Candle at four or five Paces Diſtance, does not ſo abſolutely diſappear, but that one may perceive its Light, tho' its Picture be on the *Baſis* of the Nerve; for, if it is at all ſeen, tho' ever ſo faintly, this ſhews not only that this Defect in the Sight does not proceed from the Want of the *Choroides*, but alſo that the *Retina* is not altogether inſenſible where the Nerve enters; which makes it probable, that its Inſenſibility ariſes from a Firmneſs and Calloſity that is not to be overcome but by a very ſtrong Light.

But, in other Creatures, whoſe Nerves enter at the *Axis* of the Eye, provident Nature,

to

to prevent ſo great an Inconveniency as would of Neceſſity follow from an Inſenſibility of the *Retina*, where the Nerve is inſerted, has ſoftened the *Baſis* of the Nerve into a Subſtance equally delicate and ſenſible with that of the reſt of the *Retina*. And this we take to be the Reaſon, why theſe Animals have no Defect in their Sight in the *Axis* of the Eye where the optic Nerves enter it.

A

# TREATISE

ON THE

# EYE, the Manner and *Phænomena* of VISION.

## BOOK IV.

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### CHAP. I.

*Of the different Conformations of the Eye in different Animals, and the Benefit they receive from these Conformations.*

SECT. 1. HAVING now surveyed the several Parts of the Eye, and assigned them their proper Offices, it is easy to see how the *Retina* receives the Images of Objects, and propagates them thro' the delicate Fibres of the Nerve to the com-

mon Senſory, and how all the other Parts of this beautiful little Organ concur in rendering theſe Images as clear and diſtinct as poſſible. The next Thing which falls in Order to be conſidered, is the different Conformations of the Eye in different Animals. But, having ſpent ſo much Time already, I ſhall diſpatch this Part in leſs Bounds than the Dignity of the Subject would require.

That we may therefore, with all poſſible Brevity, account for the principal Differences in the Conformation of the Eyes of different Creatures, and ſhew their Oeconomy and *Apparatus* to be ſuch as is beſt fitted for perfecting their Sight, according to the different *Mediums* they live in, and according to the different Neceſſities of Life; we ſhall reduce our Obſervations to four Heads.

1*ſt*, We ſhall account for the different Convexity of the *Cornea*.

2*dly*, The different Figure of the Cryſtalline, and the Uſe of its *Nucleus* in Fiſhes.

3*dly*, The different Figure and Magnitude of the Pupil; and,

4*thly*, We ſhall account for the Uſe and Neceſſity of that Part commonly called *Marſupium Nigrum*, which is peculiar to Birds, and never to be found in other Animals.

§ 2.

§ 2. As to the *first* of these, the different Convexity of the *Cornea*; It hath been already observed, when speaking of the Structure of the Eye, that the *Cornea* is always more protuberant and convex than the rest of the Globe; and that, in Birds, it is much more so than in Man, and the greatest Part of Quadrupeds. Now, the Use of the *Cornea*, and the aqueous Humour which lies behind it, being to begin the Refraction of the Rays of Light, which is afterwards perfected by the Crystalline and vitreous Humours, so as the Rays that proceed from the several Points of the Object may be again united, and brought together in so many corresponding Points on the *Retina*: It may be asked, how it comes to pass, that this great Convexity of the *Cornea* in Birds does not render their sight confused and indistinct, by increasing the Refraction, and making the Rays meet at some Point before the *Retina*, in like manner as in short-sighted Men, who never see Objects distinctly at an ordinary Distance, by Reason their too plump and convex *Cornea* makes the Rays conveen too soon behind the Crystalline?

To this I answer, That this great Convexity in the *Cornea* of Birds is so far from rendering their Sight confused, that it is absolutely necessary for distinct Vision; for it is to be observed, that, as in Man and Quadrupeds, the

the Figure of their Eye is almoſt ſpherical, ſo in Birds, as well as in Fiſhes, it is flat and depreſſed, both in its fore and back Parts, by which Means the *Retina* is placed near the cryſtalline Humour; and therefore, were not the *Cornea* of a Convexity agreeable to the Flatneſs of their Eyes and Diſtance of the *Retina*, the diſtinct Image of viſible Objects would fall behind it, and thereby the Sight would be rendered confuſed and imperfect, like that of old Men, who cannot ſee Objects diſtinctly, eſpecially at a ſmall Diſtance; by Reaſon their Eyes have become too flat, in proportion to the Diſtance of the *Retina*; and therefore provident Nature, who was never known to neglect any thing for perfecting the Organs of Animals, has very wiſely increaſed the Convexity of the *Cornea* in ſuch Creatures as have the *Retina* brought near to the Cryſtalline by the Flatneſs of their Eyes; for, being thereby enabled to ſee Objects diſtinctly at an ordinary Diſtance, they can, by changing the Conformation of their Eyes, adapt them to all other Diſtances neceſſary.

§ 3. The *ſecond* Thing to be inquired into, is the different Figures of the Cryſtalline, and the Uſe of the *Nucleus* or internal Cryſtalline, which is always found in the Eyes of Fiſhes.

In

In the brief Deſcription I have given of the Eye, I obſerved, that, in all Animals that live conſtantly in Air, ſuch as Man, Quadrupeds, and the greateſt Part of the Bird-kind, the Cryſtalline is always lenticular; but in ſuch as always reſide in Water, as do the greateſt Part of Fiſhes, its Figure is that of a Sphere or Globe; and in thoſe Creatures that are ſometimes upon Land, and at other times in Water, as the Sea Calf, Cormorant, *&c.* the Cryſtalline has a middle Figure betwixt that of a *Lens* and a Globe.

Theſe are the Differences which have been found in the Figures of the Cryſtalline; all which are the very beſt that could have been for perfecting the Sight of theſe Animals, and are exactly fitted to their ſeveral Circumſtances and Occaſions. For, with reſpect to Man, and ſuch Animals as live conſtantly in Air, it is not doubted, that they are of ſuch a Degree of Convexity as qualifies them for ſeeing diſtinctly at an ordinary Diſtance; and this is what all of us conſtantly experience.

But then, it may be inquired, how it comes to paſs, that, ſince in Land-Animals the lenticular Cryſtalline is ſufficient to refract the Light as much as is neceſſary for Viſion, the ſpherical Cryſtalline of Fiſhes does not, by its greater refractive Power, conveen the Rays before they come at the *Retina*, and thereby

thereby render their Sight confuſed and indiſtinct, excepting only when the Object is very nigh? To this I anſwer,

1*mo*, That the Eyes of Fiſhes are flat both behind and before, by which Means the *Retina* is not ſo far removed from the Cryſtalline as in Man and Quadrupeds whoſe Eyes are nearly a perfect Sphere; and therefore, that the Rays might be made to meet at a Point on their leſs diſtant *Retina*, it was neceſſary the Refraction ſhould be increaſed by the ſpherical Figure of the Cryſtalline.

But this is not all; for this ſpherical Cryſtalline would be more than ſufficient for the Diſtance betwixt it and the *Retina*, were it not that the Rays of Light ſuffer no Refraction in their *Cornea* and aqueous Humour. Every Body knows, that Light is never refracted, but when it falls obliquely on a Surface which interceeds *Mediums* of different Denſities; and therefore it can ſuffer no Refraction in falling upon their *Cornea* and aqueous Humour, becauſe they are of equal Denſity with the Water in which they ſwim: To compenſate which, it was abſolutely neceſſary, that their Cryſtalline ſhould have a ſpherical Figure, for increaſing its Refraction, that the Rays might be brought together to a Point in the *Retina*. But in Land-Animals, their lenticular Cryſtalline is ſufficient for that End; becauſe

the

the Rays of Light which paſs from the Object thro' the rare *Medium* Air, ſuffer a ſtrong Refraction in falling upon their convex and more denſe *Cornea;* and therefore need not afterwards ſo much Refraction in the Cryſtalline. And this is the Reaſon of that Difference that is found in the Figure of the Cryſtalline in the Inhabitants of the Air and Water.

There is yet another Advantage which Fiſhes may reap from the ſpherical Figure of their Cryſtalline, and that is, that the Eye will take in more Objects at one View, provided the Pupil be large, as is uſual in Fiſhes Eyes. The Reaſon is, that the Rays from collateral Objects fall perpendicularly upon the Sides of the ſpherical Cryſtalline, and obliquely upon a lenticular one: Conſequently, the Pictures of collateral Objects upon the *Retina*, concentric to a ſpherical Cryſtalline, will be as diſtinct as thoſe of Objects placed directly before the Eye; by this Means, Animals, whoſe Eyes are placed on each Side of their Heads, will have the Advantage of ſeeing quite round them almoſt at one View, which is a great Perfection in Viſion, and Preſervative of their Lives; and in Fiſhes it may compenſate for their Want of Hearing.

From what has been ſaid of the lenticular and ſpherical Cryſtalline, it is eaſy to ſee why this

this Humour is of a middle Figure, betwixt that of a *Lens* and a Globe, in the Sea Calf, Cormorant, *&c.* For it being neceſſary that theſe and ſuch like Animals as dive in purſuit of their Prey under Water, ſhould ſee both when in Water and upon Land; this could not be better effectuated, than by giving the Cryſtalline that middle Figure, which, as is evident, muſt refract the Rays too much when upon Land, and too little when in Water; but, by the Change that is made in the Conformaon of the Eye, they are enabled to ſee diſtinctly enough in both. Hence it is, that the Cormorant, that large voracious Bird, about the Bigneſs of a large Capon, which is the *Corvus Aquaticus Plinii*, does purſue its Prey under Water with ſuch Nimbleneſs and Agility, and for a long Time together, till at laſt it catch it, which it doth with a Dexterity that is very ſurpriſing; and therefore having firſt put an Iron Ring at the Bottom of its Neck, to the end that the Fiſh being received into the *Æſophagus*, which is very large, making a kind of Craw, may not deſcend into the Ventricle, it is frequently employed in Fiſhing, and is ſaid to afford a very agreeable Diverſion; and what adds thereto is, that, after it has ſeized a Fiſh, it always throws it up into the Air, and catches it again by the Head as it falls down, that it may ſwallow it intire,

tire, and without loſs of Time; but, becauſe of the Ring about its Neck, the Fiſh gets no further than its Gullet, which being large and yielding, ſtretches into a large Pouch or Bag, in which the Fiſh are kept till it be full, when they force it to come to Land, and throw them up intire.

§ 4. The next Thing remarkable in the Cryſtalline, is its *Nucleus*, or Kernel. In deſcribing the Eye, I obſerved, that the Cryſtalline is always of a different Conſiſtence in its outward and inward Parts, being externally like a thick Gelly, but internally, towards its Centre, of a Conſiſtence equal to that of hard Suet. This Difference is in a particular Manner remarkable in Fiſhes, who are therefore ſaid to have a double Cryſtalline, the one very ſmall and ſolid in the Centre of the other, which is larger, but of a ſofter and leſs ſolid Subſtance.

This little Cryſtalline, which is as it were a *Nucleus* or Kernel to the other, in whoſe Centre it is placed, is never found wanting in the Eyes of Fiſhes. And indeed, in all Animals, ſo far as has been obſerved, this Humour is always much ſofter externally than towards its Centre; neither is the Reaſon thereof difficult; for it is certain, from the Principles of Optics, that the Rays of Light which fall

upon the Extremities of the Cryſtalline, by reaſon of their greater Obliquity, muſt be more refracted than thoſe which fall upon its Middle near its *Axis;* by which Means they will be made to meet at different Diſtances behind the cryſtalline Humour; thoſe towards its Extremity, nearer; and theſe near its *Axis*, at a greater Diſtance; ſo that it is impoſſible for all the Rays to be united exactly at the ſame Point upon the *Retina* for rendering the Sight diſtinct; and therefore, to prevent this Inconveniency, provident Nature has very wiſely, towards the *Centre* of the Cryſtalline, made its Subſtance more denſe and ſolid, that the Rays of Light that fall on the Cryſtalline near its *Axis* may, in paſſing this *Nucleus*, have their Refraction increaſed, and by that Means may be made to converge more, ſo as to meet at the ſame Point, with thoſe that paſs the Cryſtalline towards its Edge or Extremity.

This is the Reaſon why the Cryſtalline of all Animals is more ſolid towards its Centre than externally, and why in Fiſhes this Difference is ſo remarkable; for, in them, this Humour being ſpherical, the Rays that fall thereon, at ſome Diſtance from its *Axis*, by reaſon of their great Obliquity, would be made to meet at a greater Diſtance from the Point of Union of the other Rays, that paſs near its

its *Axis*, than in Land-animals, who have this Humour lenticular; and therefore, to prevent this Inconveniency, which would have rendered the Sight prodigiously indistinct, Nature has provided them with that solid Crystalline in the Centre of the other, whose Density far exceeds that of the *Nucleus* of Land-animals.

§ 5. The *third* Difference in the Eyes of Animals, is that of the Pupil; and this is either, 1*mo*, in its Figure; or, 2*do*, in its Magnitude.

As to its Figure, we have formerly observed, that it is commonly round or circular, as in Man, Dogs, Apes, and many other Quadrupeds; as also in Birds of all Kinds, and the greatest Part of Fishes; but in Oxen, Goats, Horse, Sheep, and divers other Creatures, it is oblong or elliptical, having its greatest Diameter placed transversely towards the two Angles of the Eye.

This Difference is not the Effect of blind Chance, but of that wise Council and Design, which Nature always employs in the Formation of all the Parts of Animals, for the best Ends and Purposes; for, in Man, and other Creatures, who have occasion to see on all Hands equally, it was necessary that their Pupils should have a round Figure, that they might

see

ſee Objects above and below, and on both Sides with the ſame Facility; but, in Oxen, Sheep, and ſuch other Creatures, as almoſt always go ſeeking their Food with their Heads bowed down towards the Earth, it was ſufficient that they ſhould ſee Objects immediately before them, and on each Hand; and therefore their Pupil is made oblong, that it may receive the Rays of Light which come from Objects on either Side; which is an admirable Proviſion for theſe Creatures to ſee the better laterally, and thereby to avoid Inconveniences, as well as help them to gather their Food on the Ground both by Day and by Night. And this Figure is ſtill the more neceſſary, becauſe Dr. BRIGGS, in his *Ophthalmographia*, (*Cap.* 7.) has obſerved, that, in theſe Creatures, their Eyes cannot ſo eaſily be turned Side-ways, becauſe of the Fat which ſtraitens them in that Motion; for which Reaſon it was proper to ſupply that Defect, by making the Pupil oblong.

§ 6. Another remarkable Difference in the Figure of the Pupil, may be ſeen in Cats, in whom this Aperture is alſo oblong; but it reſembles a Fiſſure, not tranſverſely placed, as in the Creatures juſt now named, but erect, having its largeſt Diameter running perpendicularly croſs the Eye-lids; which is a beautiful

Proviſion

Proviſion for enabling this Creature to ſee beſt upwards and downwards, and to climb to and again with wonderful Swiftneſs and Agility; for this Creature, being to live chiefly on Rats and Mice, which are Animals that uſually climb and run upon ſteep Places, the moſt commodious Situation of their Pupil for diſcovering and purſuing theſe Objects, is the perpendicular.

But there is yet another remarkable Advantage this Creature receives from the Figure of its Pupil, and that is, that it can open it wide, and ſhut it up cloſe; the latter of which ſerveth to exclude the brighter Light of Day, and the former to take in the more faint Rays of the Night, thereby enabling it to ſee and catch its Prey both by Day and Night.

§ 7. For underſtanding this beautiful Mechaniſm, See PLATE I. *Fig.* 11. where ABCD is the Pupil in its dilated State, the narrow Slit AC the Pupil in its contracted State, A and C two Points in the Pupil, which are ſuppoſed fixed and immoveable, the Parallel Prickt-lines BD, EF, *&c.* Fibres of the *Uvea*, which are ſtretched by the Contraction of the Pupil, and which, by their elaſtic Contraction, dilate the Pupil, when the orbicular Fibres ceaſe to act; ABECFDA, one of the orbicular Fibres of the *Uvea* ſerving to contract the Pupil.

Now,

Now, ſuppoſing theſe orbicular Fibres in their contracted State to become a third ſhorter than when relaxed, which is the Degree of Contraction that is commonly allowed to Muſcles, it is obvious, that the Fibres ABEC, ADFC, will, when contracted to their utmoſt, coincide with the Diameter of the Pupil AC, by which means the Pupil will be quite ſhut up, and if they be leſs contracted, the Pupil will then form a long Slit, whoſe Wideneſs will be ſmaller or greater, according as the orbicular Fibres are more or leſs contracted; and if they are not at all contracted, the Pupil will then, by the elaſtic Contraction of the parallel Fibres of the *Uvea*, be made to dilate ſtill more, and by dilating will re-aſſume its large circular Form; for the natural State of the Pupil is a State of Dilatation; and I have obſerved that Cats, after Death, have the Pupil exceeding large and circular.

By this Mechaniſm, Cats are enabled to contract their large circular Pupils into a long narrow Slit, and, by ſhutting their Eye-lids, they can ſo cloſe this Slit, as to admit, as it were, only one ſingle Ray; and, by throwing all open again, they can take in all the faintеſt Rays; which is an incomparable Proviſion for this Animal, who has occaſion to watch and way-lay its Prey, both by Day and Night,

and

and to Climb. And this Mechaniſm muſt alſo take place in all other nocturnal Animals, excepting ſuch as cannot bear the Light of Day; as will appear from what is immediately to follow.

§ 8. The other remarkable Difference in the Pupil of Animals, is its Magnitude. This is chiefly remarkable in the Eyes of nocturnal Animals, ſuch as the Owl, Bat-bird, *&c.* and it is principally from this, that they are enabled to ſee by Night; for the Magnitude of the Pupil in theſe Creatures lets in a ſufficient Quantity of Light, even by Night, when it is faint and weak; but, in Day-light, the Quantity is too great to be ſuffered; and therefore, not being able to bear it, they retire to ſome dark Place, where they repoſe themſelves by Day, as other Animals do by Night; for, in them, it is otherwiſe than in Cats, who can ſee both by Day and Night. Their Pupil is circular without any fixt Points in it, and therefore it muſt contract equally all round: But the circular Fibres which ſerve to contract it, as they cannot contract more than a Third of their Length, they can only reduce the Diameter of the Pupil from 3 to 2; and therefore the Pupil itſelf, in its moſt dilated State, will be to the Pupil in its moſt contracted State, as the Square of 3 to the Square of 2, that is, as 9 is to 4. But if they can

ſee

ſee by Night, when the Magnitude of the Pupil is only equal to 9, it is obvious, that more Light muſt enter the Eye by Day, when the Pupil is equal to 4, than they can poſſibly bear. And this ſhews, that no Creature having a circular Pupil can ſee perfectly right both by Day and Night; but theſe nocturnal Creatures having no occaſion to ſee by Day, it was ſufficient that their Eyes ſhould be ſo formed, as to enable them to ſee by Night, which may be more uſeful to them: And this Nature hath taken effectual care of, by the Tranſparency of the Humours of the Eye, the Delicacy of the *Retina*, and the uncommon Magnitude of the Pupil.

§ 9. The *fourth* and laſt Thing in the Make of the Eyes of different Creatures, which we have propoſed to explain, is the *Marſupium Nigrum* or black Purſe, peculiar to Birds, and which is never to be found in any other Creature.

In the Account we have given of the Structure of the Eye, we obſerved, that, in the Eyes of Birds, there is a certain Part, in Form of a Purſe, which ariſes from the Entry of the optic Nerve, and paſſes thro' the vitreous Humour to its Inſertion in that Part of the Edge of the Cryſtalline, which is next the great *Canthus*. This Part is always covered with a black Pigment, which is of a more intenſe Colour

Colour than either that of the *Uvea* or *Choroides*: whence it is that Mr. PERRAULT, and the other *French* Academiſts, conjecture, that its only Uſe is, to aſſiſt the *Choroides* and *Uvea*, in preparing the Nouriſhment that goes to the Humours of the Eye, which, by reaſon of the tranſparent Purity that is requiſite for them, muſt have an Aliment very pure, and wholly exempt from the groſs, earthy and black Parts by which Bodies are rendered opaque; for theſe Parts which may be called the Lees of the Blood, are ſeparated therefrom, and retained in the *Choroides* and Purſe of the optic Nerve, which therefore are always ſullied and blackened therewith.

That this *Bourſe Noir*, as the *French* call it, aſſiſts the *Uvea* and *Choroides* in the Separation and Reception of the black Parts of the Blood, that the Humours of the Eye may be preſerved more pure and tranſparent, we think is beyond Diſpute; and that for theſe Reaſons:

1*mo*, Becauſe this Membrane is never found in any Creature but Birds, and that becauſe, of all Creatures, Birds have occaſion for the beſt Sight, by reaſon their Flight places them at a conſiderable Diſtance from Objects which they ought to ſee.

2*do*, Becauſe, according as Birds have occaſion for a more or leſs piercing Sight, this Part is always proportionally of a more or leſs intenſe black Colour. Thus, in Eagles, and other Birds of Prey, it is always covered with more of this black *Mucus* than in our domeſtic Birds, which either do not fly, or do not fly ſo high, ſuch as Geeſe, Hens, *&c.*

3*tio*, Becauſe in the *Demoiſelle* of *Numidia*, that ſtrange dancing or Buffoon-Bird, which is the celebrated and wonderful *Otus* of the Antients, and which, by reaſon of certain Ways of acting, wherein it ſeems to imitate the Geſtures of a Woman, who affects a Grace in Walking and Dancing, has of old by ARISTOTLE been named *Actor* or *Comedian;* I ſay, in this Bird, which is the only one wherein the *French* Academiſts found this black Purſe wanting, the *Choroides* is a great deal blacker and thicker than ordinary, as if the whole Dregs of the Blood, which in the Eyes of other Birds ſhould be retained in the *Choroides* and black Purſe, had here been collected into the *Choroides* alone.

§ 10. Theſe are the Reaſons that determine us to agree with Monſ. PERRAULT and the other *French* Academiſts, in thinking that the Uſe of this Part is to preſerve that Tranſparency in the Humours

Humours of the Eye ſo neceſſary for Viſion; tho' at the ſame time we are of opinion, that it has yet another Uſe no leſs conſiderable; which I ſhall now explain.

Every Body knows, that in Birds their Eyes are not, as in Man, Dogs, and ſuch other Creatures as look the ſame Way with both Eyes, placed in the Fore-part of their Head, but ſo much towards the Sides thereof, as makes it impoſſible for them to direct both of them to the ſame Object: Neither does this Situation of their Eyes ever allow them to be turned towards an Object placed ſtraight before them. Hence it is, you ſhall frequently obſerve, that, when any Bird wants to ſee an Object that is ſtreight before it, it does turn the Side of its Head that Way, that the Rays of Light may fall directly upon its Eye. But then their Sight muſt in ſome Degree be weaker, becauſe the Object is only ſeen with one Eye.

Now, this being underſtood, it is eaſy to ſee, that without this *Marſupium Nigrum*, it would have been impoſſible for Birds to ſee their Food wherewith they are nouriſhed; becauſe the Rays of Light that come from an Object placed near the Extremity of their Bill, would, in falling obliquely upon their Eyes, have rendered their Sight prodigiouſly confuſed

fuſed and imperfect; juſt as the Image of a Candle or other Object is confuſed when made by a *Lens* placed obliquely; for the Picture caſt on the Paper is always more and more confuſed, in proportion to the oblique Poſition of the *Lens* thro' which the Light paſſes; and therefore, to prevent this Defect in the Sight of Birds, Nature has very wiſely provided them with this Part, which being of a muſcular Subſtance, does, by its Contraction, draw the Edge of the Cryſtalline next the great *Canthus* towards the Bottom of the Eye, and render its Situation ſuch, as the Rays of Light which come from Objects placed directly before them, and towards the Extremity of their Bill, may fall upon it more perpendicularly; which was abſolutely neceſſary for rendering Viſion more diſtinct.

This is an admirable and truly ſurpriſingly beautiful Piece of Mechaniſm, for Perfecting the Sight of thoſe Animals that cannot turn their Eyes to Objects ſtraight before them. And, to confirm this Opinion, it may be worth while again to obſerve, that this *Bourſe Noir*, as the *French* call it, tho' it be tinged black like the *Choroides*, yet, if it be waſhed and cleaned, it appears to be compoſed of muſcular Fibres, not unlike the *Ligamentum Ciliare*. Nor is it any ſolid Objection to this, ſuppoſing

ſuppoſing that this Membrane ſhould not always be found inſerted into the Cryſtalline; for it being ſo firmly fixed unto, or embodied in the vitreous Humour, that the vitreous Humour hangs firmly to it, and is not ſo eaſily parted from it, all the Motions of this Membrane are eaſily communicated to the vitreous Humour, and by conſequence to the Cryſtalline, which is connected to it.

# A TREATISE

ON THE

## EYE, the Manner and Phæno-mena of VISION,

### BOOK V.

### Of the Phænomena of Vision.

A

# TREATISE

ON THE

# EYE, the Manner and *Phænomena* of VISION.

## BOOK V.

## *Of the* Phænomena *of Viſion.*

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### CHAP. I.

*Of the ſingle Appearance of Objects.*

HAVING diſpatched what we thought neceſſary for underſtanding the Fabric of the Eye, the Nature of Light, the Manner of Viſion, the Uſe of the ſeveral Parts of the Eye, and the Neceſſity of its different Conformations in different Animals; I ſhall now

now proceed to the laſt Part of the Theory of this Organ, which was, to account for the various *Phænomena* of Viſion. This is indeed a very curious and entertaining Subject; but, being very copious and fertile, it would require more Time than what I can at preſent ſpare; and therefore, that I may haſten to a cloſe, I ſhall only take notice of ſuch *Phænomena* as are moſt common and obvious, and which no body ought to be ignorant of.

§ 1. The firſt *Phænomenon* I ſhall account for, is the ſingle Appearance of Objects ſeen with both Eyes.

Why Objects ſeen with both Eyes do not appear double, is a Problem that has employed the Genius and Invention of the greateſt Men in all Ages. GASSENDUS and PORTA found ſuch Difficulty in reconciling this Appearance with the ordinary Principles of Philoſophy and and Optics, that they have been forced to ſuppoſe, that tho' both Eyes are open, yet we only ſee with one at a Time. But this being obviouſly contrary to common Experience, ſerves more as an Example to ſhew what ſurpriſing Lengths Fancy may carry even the greateſt Men, than ſatisfy the curious. *

§ 2.

* GASSENDUS gives this ſtrange Reaſon why an Object is not ſeen by both Eyes at once; becauſe, ſays he, an Object viewed firſt with one Eye alone, and then with the other, appears to cover

§ 2. GALEN imagined, that this ſingle Appearance of Objects proceeds from the cloſe Coalition of the optic Nerves behind the *Os Sphenoides*, and ſeems to triumph in the Diſcovery, as if he had found out a fine Reaſon why our optic Nerves are thus united (*Lib.* 10. *de Offic. Part. cap.* 14.) In this he is followed by a great many Philoſophers, as well as Phyſicians, tho' they are much divided among themſelves in their Manner of explaining it. GALEN himſelf had Recourſe to a Communication of Pores, and followed the Doctrine of HEROPHILUS, in giving to each Nerve one Pore, which he made to communicate at the Conjunction of the Nerves. But as this Communication of Pores is, by our beſt Anatomiſts, now looked on as mere Hypotheſis, that has no Foundation in Nature; ſo it is altogether inſufficient for ſolving the Problem; tho', in place of one Pore, each Nerve ſhould, agreeable to the more modern Notion, be allowed to have as many of them as there are nervous Fibres; as ſome of the followers of GALEN have indeed ſuppoſed.



cover different Places of a diſtant Wall; therefore, if the *Axis* of both Eyes were together directed to the Object, boththoſe Parts of the Wall, if not the whole Interval, ought to be hid. (*De apparente Magnitudine Solis humilis et ſublimis, Epiſt.* 2. *art.* 17. *pag.* 52.) But this is ſo obvious an Abſurdity, that it deſerves no Anſwer: Yet the Learned TACQUET had ſo little conſidered the Operation of the Eye, as to ſubſcribe to this abſurd Aſſertion of GASSENDUS, that the *Axes* of both Eyes are never directed to the ſame Object, (*Optic. Lib.* i. *Prop.* 2).

§ 3. Our juſtly eminent Sir ISAAC NEWTON (in the Queries annexed to his Optics) accounts for it thus; " Are not the Species " of Objects ſeen with both Eyes united, where " the optic Nerves meet before they come " into the Brain, the Fibres on the Right- " ſide of both Nerves uniting there, and, " after Union, going thence into the Brain in " the Nerve which is on the Right-ſide of the " Head; and the Fibres on the Left-ſide of " both Nerves uniting in the ſame Place, and, " after Union, going into the Brain in the " Nerve which is on the Left-ſide of the " Head: And theſe two Nerves meeting in " the Brain, in ſuch Manner that their Fibres " make but one intire Species or Picture, Half " of which, on the Right-ſide of the *Senſorium*, " comes from the Right-ſide of both Eyes, " thro' the Right-ſide of both optic Nerves, " to the Place where the Nerves meet, and " from thence on the Right-ſide of the Head " into the Brain; and the other Half, on " the Left-ſide of the *Senſorium*, comes in " like Manner from the Left-ſide of both " Eyes."

This is indeed the moſt beautiful and ingenious Explication of the Manner how an Object appears ſingle from the Coalition of the optic Nerves that ever appeared; and, to render it ſtill more probable, the ſame great Man obſerves,

obſerves, " That the optic Nerves of ſuch " Animals as look the ſame way with both " Eyes, (as of Men, Sheep, Dogs, Oxen, *&c.*) " meet before they come into the Brain; " but the optic Nerves of ſuch Animals as " do not look the ſame way with both " Eyes (as of Fiſhes, and of the Cameleon) " do not meet."

Theſe Reaſons do indeed render his Hypotheſis very probable; yet there are others ſo demonſtrative of the contrary, that it is not to be doubted, but, had they been known to NEWTON, he had retracted his Opinion, eſpecially ſince the Thing admits of an eaſy Solution, without any ſuch Suppoſition: For,

§ 4. Altho' the optic Nerves are united at the *Sella Turcica*, yet this happens without any Confuſion or Decuſſation of their Fibres. It is indeed true, that their Conjunction is ſo cloſe, that their Subſtances ſeem to be confounded; yet there are ſeveral Obſervations which prove that they are united only by a cloſe Conjunction, without any Decuſſation, Interſection, Mixture or Confuſion of Subſtance; of which I ſhall only mention two; the one is, from the accurate and faithful Anatomiſt VESALIUS. His words are: *Porro iis qui de congreſſu hoc meatuque acriter citra Partium inſpectionem indies altercantur, non gravabor*

*gravabor duo, quæ in congressu animadverti, hic adjicere, quo et hinc suarum nugarum habeant argumenta.* Patavii *itaque adolescens suspendio necatus publicæ sectioni adhibitus fuit, cui ante annum dexter oculus à carnifice erutus fuerat: deinde mulier, eodem supplicio affecta, nobis obtigit, cui dexter quoque oculus ab ineunte ætate emarcuerat, sinistro interim integerrimo. Mulieri dexter nervus toto progressu longe tenuior sinistro visebatur, non solum extra calvariæ cavitatem, verum in exortu quoque, et in dextra congressûs nervorum sede. Ac præterquam quod dexter tenuis erat, durior quoque et rubicundior cernebatur, uti sane et in adolescente: Sed dexter non admodum, neque crassitie, neque mollitie adhuc sinistro cedebat.* (*De Corp. Hum. Fabrica, Lib.* iv. *c.* 4.)

The other Observation which I shall take notice of, is from CÆSALPINUS, whose Words, as recorded by RIOLAN (*Anthropograph. Lib.* iv. *cap.* 2.) And DIEMERBROEK (*Anatom. Corp. Human. Lib.* iii. *cap.* 8.) are as follows: *Repertus est aliquando in anatome alter ex nervis visoriis attenuatus, alter plenus: Visus autem erat imbecillis in oculo ad quem nervus extenuatus ferebatur; habuit enim vulnus in capite circa eandem partem: nervus autem extenuatus non ad oppositam partem procedebat, sed ad eandem flectebatur. Visum hoc est Pisis, anno* 1590: *Unde omnes spectatores argumentum id certum existimaverunt,*

*nervos*

*nervos viſorios nequaquam ſe interſecare, ſed coire, et regredi ad eandem partem.*

From theſe and ſuch like Obſervations, it plainly follows, that our optic Nerves do not interſect each other, nor mix and confound their Subſtances, but are only united by a cloſe Coheſion, contrary to what the Opinion of NEWTON and the GALENISTS ſuppoſes.

§ 5. But this is not all; for, ſuppoſing our optic Nerves to be united in what Manner they pleaſe; yet, that the ſingle Appearance of Objects ſeen with both Eyes does not depend on this Union, ſeems evident from another Obſervation of the ſame VESALIUS, which, being a little uncommon, I ſhall alſo ſet down at Length in the Author's own Words: *His ille acceſſit* (ſays he, ſpeaking of the former Obſervations) *cujus nervos viſorios, illo de quo hic ſermo eſt congreſſu, invicem non connaſci, neque ſeſe contingere, vidimus; ſed dexter non nihil eâ ſede, qua calvariam egreſſurus fuerat, ſiniſtrorſum, et ſiniſter non nihil dextrorſum reflectebatur, quaſi non coalitûs occaſione nervi congrederentur, verùm ut commodè per ſuum foramen è calvaria procederent; potiſſimum, quum etiam hoc ductu progredientes, in oculi poſterioris ſedis medium non inſerantur. Quam ſedulò autem ac ſollicitè ejus viri, cui in eum modum nervi dehiſcebant, familiares, num illi omnia gemina perpetuo oculis obverſarentur,*

*verſarentur, interrogaverimus, neminem naturæ operum cognitione flagrantem ambigere ſat ſcio; at nihil aliud reſciſcere licuit, quam ipſum de viſu nunquam conqueſtum fuiſſe, viſuque præſtante ſemper valuiſſe, familiareſque de viſorum duplicatione nihil unquam intellexiſſe.* Seeing then that Objects have appeared ſingle to ſuch as had their optic Nerves disjoined, it muſt be allowed, that this *Phænomenon* depends on ſomething elſe than the Coaleſcence or Decuſſation of theſe Nerves.

§ 6. Others, therefore, laying aſide all the Hypotheſes that are founded upon any Coaleſcence, Contact, or Croſſing of the optic Nerves, have ſought for the Cauſe of this *Phænomenon* in a certain Sympathy betwixt them.

To explain this Sympathy, Mr. ROHAULT (*Phyſic. Part.* I. *cap.* 31.) ſuppoſes, that in each Nerve there are juſt as many Fibres as in the other; and that the correſponding Fibres of both Nerves are united in the ſame Point in the *Senſorium*; *e. g.* Suppoſe, as in TAB. II. *Fig.* 12. the Nerves compoſed of five Fibres, whoſe Extremities in the Right-eye are A, B, C, D, E, and in the other *a*, *b*, *c*, *d*, *e*; the correſponding Fibres A*a*, B*b*, C*c*, D*d* and E*e*, are ſuppoſed to meet in the *Senſorium* S, in the Points α, β, κ, δ, ε. Hence, if both Eyes are directed to F, its Image will fall on the *Retina*

*tina* at the optic *Axes*, and there ſtrike the ſympathiſing Fibres C and *c*: which Motion being propagated to the ſingle Point of the *Senſorium* ×, muſt there make but one Species or Picture. In like manner, the Eyes retaining the ſame Direction, the Image of the Point G will fall upon the Right-ſide of both Eyes, and, by ſtriking the correſponding Fibres E and *e*, will, in the *Senſorium*, make but one Impreſſion at ‹, where theſe Fibres terminate; and the Image of the Point H, by ſtriking the correſponding Fibres A and *a*, will, in the *Senſorium*, make but one Impreſſion at ». And thus, though both Eyes receive the ſame Impreſſions from Objects, yet they are not ſeen double, becauſe of theſe two Impreſſions or Images, one is only formed in the *Senſorium*.

But neither has this Hypotheſis, however ſpecious, any Foundation in Nature; for if, with DES CARTES, we ſuppoſe the *Glandula Pinealis* to be the *Senſorium*, or chief Seat of the Soul, Anatomy teaches us, that the Nerves are not inſerted into it; and if, with WILLIS, we ſhould place the *Senſorium* in the *Corpora Striata*, or any other Part of the Brain, theſe being double and alike in both Sides, can never make one individual *Senſorium*, in which all the correſponding analogous nervous Fibres are united.

§ 7.

§ 7. The judicious Dr. BRIGGS (as may be ſeen at large in the *Philoſophical Tranſactions*, and in his *Nova Viſionis Theoria*, annexed to his *Ophthalmographia*) has invented another Hypotheſis for explaining this ſuppoſed Sympathy of our Eyes, without having Recourſe to any Meeting, Communication or Conjunction of the nervous Fibres in the *Senſorium*. He ſuppoſes, that the optic Nerves conſiſt of homologous Fibres, which have their Riſe in the *Thalami Nervorum Opticorum*, and are thence continued to both *Retinæ*; and that theſe Fibres have the ſame Situation, Diſpoſition and Tenſion in both Eyes; *e. g.* He ſuppoſes, that the Fibres going to the upper Part of the *Retinæ* have a greater Degree of Tenſion; thoſe going to the under Part, a ſmaller Degree of Tenſion; and thoſe going to the correſponding Sides, correſponding Degrees of Tenſion, and ſo forth; and conſequently, ſays he, when an Image is painted on the correſponding Parts of each *Retina*, the ſame Effects are produced, the ſame Notice or Information is carried to the *Thalamus*, and ſo imparted to the Soul, or judging Faculty; for the homologous and correſponding Fibres of both *Retinæ*, upon which the Image falls, having the ſame Degree of Tenſion, may be conceived as Cords of two muſical Inſtruments in Concord and Uniſon, which, from the

the Impreſſions of Light are put into the ſame Vibrations; ſo that the Mind can have but one Senſation from the ſame Object, ſince the two Impreſſions are re-united in one by the ſimilar and like Diſpoſition of the Fibres of the two Nerves, which do ſo correſpond with each other, and which have ſuch a Conformity and Similitude in their Vibrations, that the Soul cannot hinder itſelf from identifying the two Impreſſions which it receives therefrom.

This is the Subſtance of Dr. BRIGG's Hypotheſis; to confirm which, he flies to Experience and Obſervation, pretending that this Variety of Tenſion in our nervous Fibres is owing to their greater or leſſer Flexure in the *Thalami*, which, he ſays, is manifeſt to the naked Eye; and, finding that the Fibres on the Inſide of both *Thalami* agree in Flexure, as alſo thoſe on the Out-ſide, *&c.* he concludes, that they agree alſo in Tenſion, and conſequently ſympathize by a Similitude in their Vibrations.

§ 8. But, unluckily for the Author, this curious Obſervation of his, is ſo far from confirming his Hypotheſis, that it quite undermines it; for all Objects a little to a-ſide of the Concourſe of the optic *Axes*, would then appear double, by being painted on diſſimilar Parts of the *Retina;* whereas, had he laid aſide

his Obſervation, and, with NEWTON, ROHAULT, *&c.* contented himſelf in ſuppoſing, that the Fibres on the Inſide of one Eye ſympathize with the external Fibres of the other, his Hypotheſis had not been chargeable with this Abſurdity, tho' even then many Reaſons are not wanting for rejecting it; as

1. It is a very difficult Matter to conceive, how the ſoft, tender and delicate Fibres of the *Retinæ* and medullary Part of the optic Nerves can, without breaking, ſuffer that ſtrong Tenſion which ſeems neceſſary to qualify them for being put into thoſe vibrating Motions in which he makes Viſion to conſiſt. And it is more probable, that the Impreſſions made upon our Organs produce an Undulation and Refluctuation of the Spirits, or of NEWTON's *Materia Subtilis* in the nervous Fibrils, which reaching the *Senſorium*, gives us the Ideas of Objects, than that theſe Ideas ſhould be excited by the Vibrations of the nervous Fibres themſelves. This I might eaſily evince from a great many Arguments, which I muſt not now mention, becauſe they would carry us too far out of our Road, and eſpecially becauſe, tho' we allow all Senſation to proceed from the Vibrations of our nervous Fibres, yet this does not appear ſufficient to eſtabliſh his Hypotheſis. For,

2. Sup-

2. Suppoſing all Senſation to proceed from Vibrations excited in the nervous Fibres, and that theſe Fibres, in the analogous and correſponding Parts of the *Retinæ*, have the ſame Degree of Tenſion, *e. g.* ſuppoſe the Tenſion of the ſuperior Fibres of both *Retinæ* to be the ſame, as alſo that of the inferior, but that the Fibres which terminate in the ſuperior Part are more tenſe than thoſe that go to its inferior Part: This is what our Author ſuppoſes. Now, according to this Hypotheſis, it would follow, that Viſion would be more clear and ſtrong when cauſed by Rays ſtriking the upper Part of the *Retina*, than when cauſed by Rays ſtriking its inferior Part, where the Fibres being leſs ſtretched, muſt make the Vibrations more languid and faint; and conſequently an Object placed below the optic *Axis*, by painting its Image upon the ſuperior Part of the *Retina*, would appear more clear and lively, than when it is placed above it. But this is contrary to all our Experience; and what we have ſaid of the ſuperior and inferior Fibres, holds equally in all the reſt: For Viſion being every where uniform, it is neceſſary that the Fibres, by whoſe Vibrations it is ſuppoſed to be occaſioned, ſhould be every where equally ſtretched.

3. If the Concord, Harmony and equal Tenſion of the Analogous and correſponding nervous

nervous Fibres, were the Reaſon why Objects ſeen with both Eyes appear not double, it is not eaſy to conjecture why this Depravation of Sight does not happen oftener than it is found to do in Practice, and eſpecially in ſuch as abound with ſerous and phlegmatic Humours, and whoſe Brain is moiſt and lax, and who thereby are diſpoſed to the *Gutta Serena*, or ſubject to Convulſions and other nervous Diſeaſes; for, in ſuch, the Fibres of one of the optic Nerves may eaſily happen to be relaxed, while the correſponding Fibres of the other Nerve ſtill retain their natural Tenſion: And, in particular, why did not that Woman, formerly mentioned from CÆSALPINUS, ſee Objects double, ſince one of the optic Nerves was found withered and emaciated, while the other remained moiſt, plump and juicy as before? Surely, one would expect that this could not have happened in the Nerves, without affecting the Tenſion of their Fibres, and thereby have occaſioned Objects to appear double; yet no ſuch Thing happened; for every thing appeared ſingle as before, only the Sight of the diſeaſed Eye was more faint and obſcure than in the other. From which it follows, that the Cauſe of this *Phænomenon* is to be ſought for ſomewhere elſe, than in the ſimilar Situation, Diſpoſition and Tenſion of the nervous *Fibrillæ*.

§ 9.

§ 9. The true cauſe why Objects appear not double tho' ſeen with both Eyes, to me ſeems wholly to depend on the Faculty we have of ſeeing Things in the Place where they are. But, to explain and confirm this, I muſt premiſe the following

## LEMMA.

§ 10. *Every Point of an Object appears and is ſeen without the Eye, nearly in a ſtraight Line drawn perpendicularly to the* Retina *from that Point of it where its Image falls.*

That this is true, we may gather from many Experiments. The following is very eaſy and convincing:

Suppoſe E the Globe of the Eye, furniſhed with all its Coats and Humours (See PLATE II. *Fig.* 13. and 14.) and let A be a ſmall Object, ſuch as the Head of a Pin, whoſe Diſtance from the Eye muſt be greater or leſs than that at which an Object would be moſt diſtinctly ſeen when viewed with the naked Eye; cloſe to the Eye, place a Card, or Piece of opaque Paper, in which is a ſmall Hole made with a Pin, and let Q T repreſent the Card. If this Hole be ſuppoſed at *x*, then the Ray of Light A *x n*, falling on the *Retina* at *n*, will there paint the Image

Image of the ſmall Object A, and make it appear in the viſual Line *n x* A, which is perpendicular to the *Retina* at the Point *n*. But, if the Card be brought lower, ſo as its ſmall Hole may be at *r*, the Ray of Light A*r*, after paſſing the Hole, will be refracted in the Eye, ſo as to fall upon the *Retina* at ſome other Point, as *m*; for the Object A being ſuppoſed at a greater or leſſer Diſtance than that at which an Object may be moſt diſtinctly ſeen with the naked Eye, all its Rays that paſs the Pupil muſt be made to converge to a Point, either before or behind the *Retina*, ſuch as *o*: But on the *Retina* itſelf they muſt fall on different Points, according to the Situation of the Hole thro' which they paſs; for the Eye does not change its Conformation, and adapt itſelf to the Diſtance of an Object viewed thro' a perforated Card, as it always does when Objects are viewed naked, without any ſuch Interpoſition. Now, the Object A ſeen thro' the Hole *r*, does not appear in its real Place A, but at ſome other Place, as B, *viz.* in the Right-line *m*B, which is perpendicular to the *Retina* at the Point *m*; and if the Card be raiſed, ſo as the Ray A*d* may paſs the Hole at *d*; after Refraction, it will fall upon the *Retina* at *i*, and the Object will appear nearly at C in the Perpendicular *i*C.

In

In like manner, if the Card be pierced with three ſmall Holes, whoſe Diſtance does not exceed the Diameter of the Pupil, as in *d*, *x* and *r*, then the little Object A, will at the ſame time be ſeen in three different Places C, A and B, and muſt therefore appear multiplied according to the Number of Holes; which evidently proves, that the Rays that flow from the Object thro' theſe Holes, fall upon different Points of the *Retina;* and that there are three Lines drawn perpendicularly from theſe Points in the *Retina*, in each of which the Object is diſtinctly ſeen.

We might here obſerve, that if the Object A be brought to that preciſe Diſtance from the Eye that is neceſſary for uniting all its Rays in one ſingle Point of the *Retina*, as *n*, then it will appear ſingle, tho' viewed thro' ſeveral Holes. And the ſame Thing muſt happen tho' the middle Hole be covered, ſo as no Rays fall upon the Eye, but what paſs at the Holes *d* and *r*, towards the Extremities of the Pupil; for theſe Rays being united in the *Retina* at *n*, the Object will be ſeen in the viſual Line *nx*A, tho' no Rays paſs that Way. From all which, it is evident, that every little Object, or Point of an Object, appears and is ſeen in the viſual Line drawn perpendicularly to the *Retina* at that Point of it where its Image falls.

To

To make this Experiment with Exactneſs, you muſt, for an Object, look to a ſmall luminous Point in a dark Place, ſuch as a little Hole in a Card placed before a Candle, or elſe you muſt look to a ſmall black Object placed on a white or luminous Surface; as has been obſerved by SCHEINER (*Fundament. Optic.*) who has ſeveral other curious enough Obſervations relative to this Experiment. Any Trials I had occaſion to make ſucceeded well enough, with a Pin placed before a well lighted Window.

§ 11. It is from this Principle, that, when a Man in the Dark rubs the under Part, or either Corner of his Eye, with his Finger, and turns his Eye away from his Finger, he will ſee, towards the oppoſite Side of the Eye, a Circle of Fiery Colours, like thoſe in the Feather of a Peacock's Tail; which can ariſe from nothing but ſuch Motions excited in the *Retina*, by the Preſſure aud Motion of the Finger, as at other Times are excited there by Light coming from the oppoſite Side for cauſing Viſion. Whence this Experiment may be of Uſe in diſtinguiſhing a Cataract that admits of the Operation, from one that is complicated with an *Amauroſis*, or *Paralyſis* and Inſenſibility of the Nerve: For if in rubbing the Eye in the Manner juſt now mentioned, no coloured Circle appears, it is a Sign that the

the Nerve is Paralytic, and that nothing is to be expected from the Depreſſion of the Cataract; whereas, on the contrary, the Appearance of ſuch a Circle, plainly ſhews, that the Nerve is not affected, and conſequently that the Succeſs of the Operation is not to be wholly deſpaired of, even tho' the Pupil ſhould be without Motion; for ſuch an Immobility of the Pupil does not always proceed from an Inſenſibility of the Nerve, but is alſo ſometimes occaſioned either by the Preſſure of the Cataract againſt the *Uvea*, or by their Adheſion; neither of which are eſteemed ſufficient to render the Operation always fruitleſs.

It is likewiſe from this Principle, that an Object ſeen thro' a Priſm appears ſo far removed from its true Place, and that an Object ſeen thro' a *Polyedron*, or Multiplying-glaſs, appears in ſo many Places at once, and therefore appears as often multiplied.

The ſame Principle is alſo confirmed, from the erect and natural Appearance of Objects, tho' their Image on the *Retina* be inverted. Thus (in *Fig.* 12. PLATE II.) H, the lower Part of the Object GH, is projected on *a*, the upper Part of the Eye; and the higheſt Part G is projected on *e* the loweſt Part of the Eye, which makes the Image or Repreſentation *a e*,

inverted: Yet, becauſe the Point G appears without the Eye in the Line *e*G, and the Point H in the Line *a*H, the Point G muſt of Neceſſity be ſeen higher than the Point H.

What hath occaſioned ſome ſeeming Difficulty in the Buſineſs of erect Appearances, is the groundleſs Suppoſition, that the Eye or rather the Soul by means thereof, ſees an inverted Image of the external Object painted on the *Retina*, and that it judges of the Object from what it obſerves in this Image. But this is a vulgar Error; and I appeal to any one's Experience, whether he ever ſees any ſuch Thing, and every one is himſelf beſt Judge of what he ſees. And as the Mind ſees not any Image on the *Retina*, ſo it takes no Notice of the internal Poſture of the *Retina*, or of the other Parts of the Eye, but uſeth them as an Inſtrument only for the Exerciſe of the Faculty of Seeing; and therefore, when the *Retina*, on its lower Part at the Point *e*, receives an Impulſe or Stroke from the Rays that come from the upper Part of the Object G, is it not more natural, as well as uſeful, that the Mind, without any Regard to the Situation of that Part of the *Retina*, ſhould, agreeable to the Principle here laid down, be directed to conſider the Stroke as coming from the upper Part of the Object G, rather than

from

from its lower Part H; and conſequently to conclude the Cauſe of it, or the Object itſelf, there alſo? And what is ſaid of upper and lower, holds equally in *ſiniſter*, *dexter*, and all other Parts of the Object.

This may be illuſtrated, by conceiving a blind Man, who, holding in his Hands two Sticks that croſs each other, doth with them touch the Extremities of an Object placed in a perpendicular Situation: It is certain, this Man will judge that to be the upper Part of the Object which he touches with the Stick held in the undermoſt Hand, and that to be the lower Part of the Object which he touches with the Stick in his uppermoſt Hand.

## SCHOLION.

§ 12. *The Judgments we form of Objects being placed without the Eye in thoſe perpendicular Lines, or, which is nearly the ſame Thing, the Judgments we form of the Situation and Diſtance of viſual Objects, depend not on Cuſtom and Experience, but an original, connate and immutable Law to which our Minds have been ſubjected from the Time they were at firſt united to our Bodies.*

That

That the Truth of this may appear, it muſt be remembered, that all our Perceptions are preſent with the Mind, of which, properly ſpeaking, they are only Modifications, ariſing from the Motions excited in the *Senſorium*; and, when we imagine that the Colours we ſee are in the external Object, this certainly is not a Perception, but a fallacious Judgment or Concluſion, whereby we attribute that which is truly preſent with our Mind, and which our Mind feels or perceives, to external Objects.

Now, ſince there is no eſſential or neceſſary Connection betwixt theſe Perceptions and the Judgments we form concerning them, it follows, that theſe Judgments muſt either depend on Cuſtom and Experience, or on an original, connate and immutable Law.

§ 13. That all of them ſhould depend on Cuſtom and Experience, is a Contradiction in Terms; it being impoſſible for us to have any Experience, till ſome how or other we have formed a Judgment; which Judgment muſt therefore depend on an original, connate and immutable Law, that cannot but obtain, at leaſt, in ſome of our Senſations. To ſay otherwiſe, is to ſay ſomething very abſurd; it is to ſay, we judge by Experience that has never been experienced. Hence it is plain, that,

that, when one ſays, The Mind, by Cuſtom and Experience, comes to conclude what it ſees to be without the Eye in ſuch perpendicular Lines; this Experience cannot be meant of Sight, but of ſome of our other Senſes, ſuch as that of Feeling or Touch, which therefore, by virtue of a connate and immutable Law, muſt naturally and of itſelf, without any Aſſiſtance from the other Senſes, form a Judgment concerning its own Perceptions, and conclude that they are not in the Mind, but in ſomething external.

§ 14. But if, by the Touch alone, we can judge thus of the Situation and Diſtance of external Things, I ſee not why the ſame Power ſhould be denied to the Sight. It cannot be ſaid that it is more difficult for the Mind to trace back the Perceptions it has by Sight, from the *Senſorium* to the *Retina*, and from thence along thoſe perpendicular Lines to the Object itſelf, than it is to trace back the Perception it has by Touch, from the *Senſorium* along the Nerves, to the external Object occaſioning them. The ſubjecting our Minds to a Law in Seeing, is as eaſy as ſubjecting them to a Law in Feeling; and that in Feeling our Mind muſt be ſubjected to a Law, directing it to conſider its own Senſations as belonging to external Objects, has been juſt now ſhown.

And

And this ſhews the Tenor and Courſe of Nature, and makes it highly probable, that the ſame thing obtains in our other Senſes; for Nature is very conſonant and conformable to herſelf, and very ſimple and uniform; ſhe never performs ſimilar and like Effects in divers Manners, and by diſſimilar and unlike Means: This were to deſtroy that Simplicity and Uniformity which is the Beauty of all her Works, and which ſhe is obſerved to delight ſo much in.

§ 15. Were not the Mind in Seeing ſubjected to a Law, whereby it traces back its own Senſations from the *Senſorium* to the *Retina*, and from thence along the perpendicular Lines above named to the Object itſelf, and thence concludes what it perceives to be in the external Object, and not in the Mind; it is plain, that a Man born blind, being made to ſee, would at firſt have no Idea of Diſtance or Situation by Sight; the Sun and Stars, the remoteſt Objects, as well as the nearer, would all ſeem to be in his Eye, or rather in his Mind; and, if ſo, whence is it he comes afterwards to judge what he ſees to be in the external Object? This cannot proceed from Experience alone; for tho' by the Touch, we have frequently experienced the Exiſtence, Diſtance, and Situation of Things external, and found theſe Ideas to have been preceeded by

by certain correſponding viſible Ideas, I ſee not how, upon perceiving any viſible Idea preſent with our Mind, we ſhould judge it to be without in the external Object, without ſubjecting our Mind to an arbitrary irreſiſtible Law directing it ſo to do. This were to eſtabliſh an eſſential and neceſſary Connection betwixt theſe Judgments and the Experiences we have by Touch laid up in our Memories: Whereas, it is plain, no ſuch Thing can be; all the Connection that is being only cuſtomary and experimental. And ſeeing Nature, at any rate, muſt be at the Charge of a Law, is it not more reaſonable to ſuppoſe, that, by the Sight alone, without any Aſſiſtance from the other Senſes, the Mind, in conſequence of ſuch a connate and immutable Law, as has been allowed it in the Judgments it forms by Touch, ſhould be enabled to trace back its own Perceptions in the ſo often named perpendicular Lines, to the Object itſelf, and thence to form a Judgment of its Diſtance and Situation? I ſay, is not this more reaſonable, than to ſuppoſe, that we ſtand in need of the Experiences of Touch? Could theſe Experiences be of any Uſe without a new Law, there might be ſome Pretence for ſuch a Suppoſition; but this being impoſſible, it follows, that the Judgments we form of the Situation and Diſtance

ſtance of viſual Objects, depend not on Cuſtom and Experience, but on an original, connate and immutable Law, to which our Minds have been ſubjected from the Time they were firſt united to our Bodies. To ſay otherwiſe, is to ſay, that our Sight is leſs perfect than our Touch; not from any Neceſſity in the Thing itſelf, but from an Error or Miſtake in Nature. It is to make Nature do ſomething in vain, and to be luxuriant in ſuperfluous Cauſes; which is to break down the catholic and fundamental Rules of Philoſophizing, eſtabliſhed by NEWTON in his *Principia Philoſophiæ*. It is to maintain, that one accuſtomed from the Birth to ſee Objects thro' a Priſm or *Polyedron*, and not otherwiſe, would ſee Objects as other Men do, without any ſuch Interpoſition; which to me ſeems very abſurd and ridiculous.

§ 16. From what has been ſaid, I think the Truth of our *Scholium* is ſufficiently evident: But becauſe Dean BERKELEY, in his *Theory of Viſion*, has a good deal of ſubtile Reaſoning in favour of Cuſtom and Experience, that has not yet been taken notice of, I ſhall ſtop a little to conſider it.

He obſerves, that, in Seeing, the Mind, ſtrictly ſpeaking, perceives nothing but what is preſent with it; and thence concludes, that the

the Ideas of Space, Outneſs, Diſtance, and of the Situation and Magnitude of Things placed at a Diſtance, cannot, by the Sight alone, be introduced into our Minds; but that, having of a long Time experienced certain Ideas perceivable by Touch, to have been connected with certain Ideas of Sight, we do, upon perceiving theſe Ideas of Sight, forthwith conclude, what tangible Ideas are, by the wonted ordinary Courſe of Nature, like to follow; and thus, by a habitual or cuſtomary Connection, that has grown up between theſe two Sorts of Ideas, the latter are always ſuggeſted by the former, juſt as Things are ſuggeſted by Words, and Shame by Bluſhing: So that, according to him, when a Man is ſaid to ſee the Magnitude, and Situation of this or that diſtant Object, nothing is meant, but that the Ideas of Sight which are preſent with the Mind, ſuggeſt to his Underſtanding, that, after having paſſed a certain Diſtance, in ſuch a Direction, to be determined by the Motion of his Body, which is perceivable by Touch, he ſhall come to perceive certain tangible Ideas, which have been uſually connected with them; but becauſe there is no eſſential or neceſſary Connection between the Ideas of Sight and Touch, the Ideas ſuggeſted by Sight of the Diſtance, Situation and Magnitude of external Things, muſt depend intirely on Cuſtom and

Experience; for that one Idea may ſuggeſt another to the Mind, it is ſufficient that they have been obſerved to go together, without any Demonſtration of the Neceſſity of their Co-exiſtence, or without ſo much as knowing what it is that makes them ſo to co-exiſt. Thus, Words ſignify Things, for no other Reaſon, than barely becauſe they have been obſerved to accompany them.

In anſwer to this, I muſt aſk Mr. BERKELEY, how it appears that the Ideas we have by Sight of the Diſtance, Situation and Magnitude of external Things are nothing but the tactile Ideas ſuggeſted to our Minds? When my Eyes are ſhut, I can, at pleaſure, recal to Mind the Ideas of Touch, which former Senſations had lodged in my Memory; the bare naming the Thing doth preſently ſuggeſt them, as well as the ſeeing it. But there is no body who doth not perceive the Difference in himſelf, between actually looking upon an Object, and contemplating the Idea he has of it in his Memory; and therefore he hath certain Knowledge that they are not both Memory or Fancy. But this is not all: For,

Tho' it muſt be acknowledged, that, in ſeeing Objects, the Mind, ſtrictly ſpeaking, perceives nothing but what is preſent with it; yet it does not from thence follow, that the Ideas of Space, Outneſs, Diſtance, and of the Situation

Situation and Magnitude of Things placed at a Diſtance, cannot, by the Sight alone, be introduced into our Minds. Were this true, I ſee not how we could ever come by thoſe Ideas; for the tangible Ideas are as much preſent with the Mind as the viſible Ideas, and, on that Account, muſt be equally incapable of introducing the Idea of any Thing external. When with my Hand I touch an Object, the Idea perceived is preſent with my Mind; and, in moving my Hand along the Object, or in moving my Body from one Place to another, the Ideas or Perceptions that ſucceed one another, are all of them as much preſent with my Mind, as any viſible Idea can be. How then can it be ſaid, that *external Diſtance and Situation are only determined by the Motion of the Body perceivable by Touch?* This is to deſtroy the univerſally received Notions we have of Things, and to confound external Space, Diſtance and Situation, with a Series of Ideas ſucceeding one another in the Mind. It is to take away all Difference between Space and Time, and to make both conſiſt in a Conſciouſneſs of a Succeſſion of different Ideas or Perceptions in the Mind; whereas it is certain, that neither of them depends on our Ideas, but muſt continue the ſame, whether we have any Ideas or not. It is to introduce a wild and unbounded *Scepticiſm* a Scepticiſm that at once baniſhes

baniſhes this external World, and Space itſelf, out of the Field of Exiſtence, and, in place thereof, ſubſtitutes a viſionary World, a World of Ideas and Phantoms, exiſting no where but in his own Mind. It is to ſuppoſe, that it is God who preſents the Appearances of Things external to us; and that he does it in ſuch a Manner as to deceive us; for, ſuppoſing Things external to exiſt, I ſee not what greater Aſſurances we could have of their Exiſtence, than we now have. In fine, this is not to ſolve the Problem, Whether it be from Cuſtom and Experience, or by virtue of an original connate Law, that, by Sight, we come to judge of the Situation of external Things, but, by exterminating all Things external, to make the Problem itſelf abſurd and ridiculous.

§ 17. If what has been demonſtrated in the preceeding *Lemma* be duly attended to, it will not be difficult to explain how Objects ſeen with both Eyes appear ſingle, from their being ſeen by each of them in the ſame Place.

For illuſtrating this, let it be ſuppoſed, that both Eyes are directed to the Point F, (See *Fig.* 12. PLATE II.) by the preceeding *Lemma*, this Point muſt be ſeen by the Left-eye in its *Axis* cF, and by the Right-eye in its *Axis* CF; and ſince we have alſo a Faculty of judging of the Diſtance of Objects, it follows, that the

the Point F muſt be ſeen by both Eyes in that preciſe Place where the Lines *c*F, CF interſect each other; and being ſeen in the ſame Place by both Eyes, it muſt neceſſarily appear ſingle, it being impoſſible for us to conceive two Objects exiſting in the ſame Place at the ſame Time.

In like Manner, all the other viſual Points of the Object GH, muſt alſo appear ſingle: For, ſuppoſing the Eyes to continue their former Direction, the Rays which come from any other Point, as H, will be united on the *Retina* of the Left-eye on the out-ſide of the optic *Axis* at *a*; and in the other Eye, they will be united on the Inſide of its *Axis* at A: Hence the Point H will be ſeen by both Eyes in the Lines *a*H, AH, which are perpendicular to the *Retina* at the Points *a* and A, where the Image is painted. But the Lines *a*H and AH, meet and interſect each other at H; and therefore ſince our Mind, or viſive Faculty, has a Power of judging rightly of the Diſtance of Objects, it follows, that the Point H muſt be ſeen by both Eyes in the preciſe Point H, where theſe Lines interſect each other, and conſequently muſt appear ſingle, becauſe we can have no Idea of the Penetration of Matter, or, which is the ſame Thing, it is impoſſible for us to conceive two viſible Objects

jects placed in the ſame Place at the ſame Time.

§ 18. What hath been juſt now ſaid of the ſingle Appearance of Objects ſeen with both Eyes, holds only with reſpect to Objects placed in the Plan of the *Horopter*; for all Objects placed out of this Plan, muſt, in conſequence of the Principle laid down in the foregoing *Lemma*, be ſeen in two different Places, with Relation to that Point of the *Horopter* on which our Eyes are fixed; and being ſeen in two different Places, muſt therefore appear double, as ſhall be ſhewn below, *Sect.* 22.

§ 19. In the mean time, from what hath been juſt now ſaid, it follows, that the ſingle Appearance of Objects placed in the Plan of the *Horopter*, does not ariſe from the uniform Motion of our Eyes, as ſome have imagined, who therefore maintain, that this ſingle Appearance is one of the final Cauſes of the uniform Motion of our Eyes; for while the Left-eye is directed to F, (*Fig.* 12. PLATE II.) let the other be directed to G, or H, it is plain, from the preceeding *Lemma*, that the Points G, F and H, will continue to be ſeen in the ſame perpendicular Lines EG, CF, AH, they formerly appeared in, when both Eyes were directed to F; for theſe Lines, notwithſtanding the Motion of the Eye, will ſtill be perpendicular

pendicular to the *Retina* at the Points E, C and A, where the Image of theſe Points are painted, becauſe they paſs thro' the Centre of the Eye which is immoveable; and ſince at the ſame Time we have a Power of judging rightly of their Diſtance, it follows, that here alſo they muſt appear ſingle, from their being ſeen in the ſame Place by both Eyes. And this is the Reaſon why thoſe who from Uſe and Cuſtom, have acquired a Power and Habit of ſquinting, ſee Objects ſingle as other Men.

§ 20. How this agrees with the double Appearance of Objects, when either of the Eyes is, by the Preſſure of the Finger, or by a Spaſm or *Paralyſis* in any of its Muſcles, reſtrained from following the Motion of the other, is a Matter of very great Difficulty, and therefore deſerves well to be carefully examined.

It hath been ſhewn, that Objects are ſeen without the Eye, in Lines drawn perpendicularly to the *Retina*, at that Point of it where their Image is painted. It hath likewiſe been demonſtrated, that theſe Lines continue invariably the ſame, without any Change of Situation, though the Eye be turned away from the Object to which the other Eye is directed; whence it ſeems to follow, that the Object, in all Situations of the Eye, ſhould continue to be ſeen

ſeen in the ſame Place by both Eyes; and, being ſeen in the ſame Place, ſhould always appear ſingle. How comes it therefore, that, in the Caſe before us, the Object ſhould appear double? What is it can put this Cheat upon the Underſtanding? Whether the Eyes look the ſame Way, or differently, the Object appears to each of them in the ſame Lines; and ſince, at the ſame Time, we alſo perceive its Diſtance, it ought to appear ſingle, becauſe ſeen in the Concourſe of theſe Lines, and yet it is eſteemed double. Herein conſiſts the Difficulty which yet does vaniſh and admit of a moſt eaſy Solution, if we but conſider that the Mind miſtakes the Situation of the Eye, and ſuppoſes that it is directed to the ſame Object with the other; for, having been accuſtomed to move both Eyes uniformly, from which a Kind of Neceſſity has ariſen that makes it impoſſible for us to move them differently, when we would view any Object, the Mind wills both Eyes to be directed towards it, and, not being ſenſible that either of them has diſobeyed its Commands, it concludes, that they are both turned the ſame Way, becauſe it has been accuſtomed to find them ſo upon the like Occaſions: And being thus miſtaken as to the Situation of the Eye, it muſt alſo be miſtaken as to the Situaon of the Lines in which the Object is ſeen,

which

which therefore muſt be ſeen double, by Reaſon of the different Situation it appears in to each Eye; it being impoſſible for us to conceive that any one Thing can be in two different Places at the ſame Time.

To illuſtrate this Matter, let it be ſuppoſed, that one wills both Eyes to be directed to F, (See ſtill *Fig.* 12. PLATE II.) for viewing it accurately, and that while the Left-eye gives ready Obedience, let the other, by Reaſon of a recent Defect in ſome of its Muſcles, be turned to H: It is plain, that the Point F will be ſeen in the ſame perpendicular Line CF it would have appeared in had the Eye been directed to F: But, becauſe this Line, by Reaſon of the Obliquity of the Eye, does not fall on the *Retina* at its *Axis* C, but at ſome other Point on the Out-ſide of this *Axis*, as E, ſo that the Angle C*o*E may be equal to the Angle F*o*H; it will itſelf appear tranſlated to EG; and, being thus tranſlated, the Point F muſt be tranſlated with it, which therefore will be ſeen, not in its proper Place F, but in ſome other Place, as G, ſituated in the Perpendicular E*o*G: For ſince the Mind knows not but the Eye is directed to F, it muſt form the ſame Judgment with reſpect to the Situation of Objects, as if it were really ſo: But it has been already ſhewn, that Objects are always ſeen by virtue of a connate immutable Law, in Lines

drawn perpendicularly to the *Retina*, from that Point of it where their Image falls; and therefore the Object F, having its Image painted on the *Retina* at E, muſt be ſeen by this Eye, which the Mind ſuppoſes directed to F, ſomewhere in the Perpendicular E G, as at G, while to the other Eye it appears in its true Place F; and, being thus ſeen in two different Places, G and F, it muſt neceſſarily appear double.

The Caſe here is exactly the ſame, as if, when one looks with both Eyes at any ſmall Object ſtraight before him, he ſhould imagine his Right-eye to be turned outwards towards his Right-hand; for the little Object will by that Eye be judged on the Right-hand, becauſe its Picture is made on the *Retina* at the *Axis* of the Eye, which he ſuppoſes is directed that way, while to the other it appears in its true Place, and therefore will appear double.

Something like this happens when an Object is felt by the Extremities of two Fingers that are made to croſs each other; for the Mind, not attending to the poſition of the Fingers, judges that the Object is double, becauſe it is felt by thoſe Parts of the Fingers that uſed to be at a Diſtance from each other.

§ 21. That we have here given the true Account of this *Phænomenon*, will be further evident

evident to any one who conſiders, that, when the Mind does not miſtake the Situation of the Eye, as in thoſe who by Cuſtom have, from their Infancy, contracted a Habit of moving their Eyes differently, all Objects appear ſingle as to other Men; and this likewiſe is the Reaſon why, in the Caſe before us, all Things come in Time to be ſeen ſingle; for, by repeated Experiences, the Mind becomes wiſer, and by Degrees learns to form a right Judgment concerning the Direction of the Eye; which Judgment, by becoming habitual, muſt ſerve to correct the Miſtake it was formerly led into with reſpect to the Situation of Objects. The ingenious Mr. CHESELDEN gives us a very beautiful Example of this in his Syſtem of Anatomy. His words are: "A Gentleman, who, "from a Blow on the Head, had one Eye "diſtorted, found every Object appear double; "but, by Degrees, the moſt familiar Ones "became ſingle, and in Time all Objects "became ſo, without any Amendment of the "Diſtortion."

The not conſidering of what has been ſaid, has been a fundamental and perplexing Overſight; for Proof whereof, we need go no further than the Caſe before us: For explaining which, many learned Men have been forced to ſuppoſe, that, by Sight alone, we can never form any Judgment with reſpect to the Situation

tion of Objects, without calling in the Experiences of Touch; the contrary of which has been ſet forth at large, and demonſtrated in the preceeding *Scholion*.

From all that has been ſaid on this Head, laid together, and duly conſidered, we may clearly deduce this Inference. The double Appearance of Objects that happens when either of the Eyes is, from a Spaſm or *Paralyſis* of any of their Muſcles, or from any other Cauſe, reſtrained from following the Motions of the other, does not prove, that, to ſee Objects ſingle, it is abſolutely requiſite that both Eyes be directed to the ſame Object, and that this is one of the final Cauſes of their uniform Motion.

§ 22. But, that this may appear yet more plainly, I ſhall here Explain how it comes to paſs, that all Objects placed out of the Plan of the *Horopter* are always ſeen in two different Places, with relation to the Point of the *Horopter* on which our Eyes are fixed, and, being ſeen in two different Places, do therefore appear double.

Thus, if, while the optic *Axes* (See *Fig.* 15. PLATE II.) AC, BC, are directed to a mark C, for viewing it accurately, we attend to an Object *x*, placed any where within the Angle ACB, formed of the optic *Axes*, the Object *x* will appear in two Places; for being ſeen by the

the Right-eye, in the Direction of the viſual Line B*x*, it muſt appear on the Left-ſide of C, and its Diſtance from C will be meaſured by the Angle C B*x*; and, being ſeen by the Left-eye in the Direction of the viſual Line A*x*, it muſt appear on the Right-ſide of C, and its Diſtance from C will be meaſured by the Angle C A*x*; and conſequently it muſt appear double, and the Diſtance between the Places of its Appearance will be meaſured by the Sum of the Angles C B*x*, C A*x*.

For the like Reaſon, ſo ſoon as the Eyes change their Direction from C to *x*, the Object *x* ſhall appear ſingle; but all other Objects placed within the Angle D*x*E, made by the optic *Axes* produced, will appear double. Thus the Object C being ſeen in the viſual Lines AC, BC, which are on different Sides of the Object *x*, it muſt neceſſarily appear double, and the Diſtance between the Places of its Appearance is meaſured by the Sum of the Angles CAE, CBD.

The ſame way of Reaſoning applied to Objects in all manner of Situations, will ſhew, that all of them muſt appear double when placed out of the Plan of the *Horopter*: All which is exactly agreeable to Experience. And this alſo is the Reaſon why a double Appearance will be ſeen, when the End of a long Ruler is placed between the Eye-brows, and extended

extended directly foreward with its flat Sides reſpecting right and left; for, by directing the Eyes to a remote Object, the Right-ſide of the Ruler ſeen by the Right-eye will appear on the Left-hand, and the Left-ſide on the Right-hand.

23. From what hath been ſaid, it were eaſy to explain the Nature of Squinting, and, from the above eſtabliſhed Principles, to ſet the Diagnoſtics and Prognoſtics of this Diſeaſe in a juſter Light than hitherto has been done: For which Purpoſe, I ſhall take a View of the ſeveral Cauſes from which it may be ſuppoſed to proceed, and ſhall determine ſome of the chief optical Effects that naturally ariſe from them, whereby the preceeding Doctrine will be further illuſtrated and confirmed. And,

*Firſt*, This Diſeaſe may proceed from Cuſtom and Habit, while in the Eye itſelf, or in its Muſcles, nothing is preternatural or defective.

Thus Children, by imitating thoſe that ſquint, and Infants, by having many agreeable Objects preſented to them at once, which invite them to turn one Eye to one, and the other Eye to another, do frequently contract a Habit of moving their Eyes differently; which afterwards they cannot ſo eaſily correct. Infants likewiſe get a Cuſtom of Squinting, by being

being placed obliquely towards a Candle, Window, or any other agreeable Object capable of attracting their Sight; for tho', to ſee the Object, they may at firſt turn both Eyes towards it, yet, becauſe ſuch an oblique Situation is painful and laborious, eſpecially to the moſt diſtant Eye, they ſoon relax one of the Eyes, and content themſelves with examining it with the Eye that is next it; whence ariſes a Diverſity of Situation, and a Habit of moving the Eyes differently.

In this Caſe, which may admit of a Cure, if not too much confirmed, it is evident, that Objects will be ſeen in the ſame Place by both Eyes, and therefore muſt appear ſingle as to other Men; but becauſe in the Eye that ſquints, the Image of the Object to which the other Eye is directed falls not on the moſt ſenſible and delicate Part of the *Retina*, which is naturally in the *Axis* of the Eye, it is eaſy to ſee, that it muſt be but faintly perceived by this Eye. Hence it is, that, while they are attentive in viewing any Object, if the Hand be brought before the other Eye, this Object will be but obſcurely ſeen, till the Eye change its Situation, and have its *Axis* directed to it; which Change of Situation is indeed very eaſy for them, becauſe it depends on the Muſcles of the Eyes, whoſe Functions are intire; but, by Reaſon of the Habit they have contracted

of

of moving their Eyes differently, the other Eye is at the ſame Time frequently turned aſide, ſo that only one at a Time is directed to the Object.

That all this may be the better perceived, for an Object, cauſe them to look at the Image of the upper Part of your Noſe in a plain Mirror, while you ſtand directly behind them, to obſerve the Direction of their Eyes.

§ 24. *Secondly*, The *Strabiſmus* may proceed from a Fault in the firſt Conformation, by which the moſt delicate and ſenſible Part of the *Retina* is removed from its natural Situation, which is directly oppoſite to the Pupil, and is placed a little to aſide of the *Axis* of the Eye; which obliges them to turn away the Eye from the Object they would view, that its Picture may fall on this moſt ſenſible Part of the Organ. Thus, if *a* (ſee *Fig.* 12. PLATE II.) be ſuppoſed the moſt ſenſible Part of the *Retina*, in order to ſee the Object H, the Eye muſt be turned aſide to F.

When this is the Caſe, the Diſeaſe is altogether incurable, and the *Phænomena* that ariſe therefrom differ in nothing from the *Phænomena* of the former Caſe, excepting only that here: 1*mo*, The Object to which the Eye is not directed will be beſt ſeen, which is the

the reverſe of what happens when this Diſeaſe ariſes barely from Habit and Cuſtom.

2*do*, No Object will appear altogether clear and diſtinct; for all Objects to which the Eye is directed, by having their Image painted on the *Retina* at the *Axis* of the Eye, where it is not very ſenſible, will be but obſcurely ſeen; and Objects that are placed ſo far to a Side of the optic *Axis* as is neceſſary for making their Image fall on the moſt ſenſible and delicate Part of the *Retina*, muſt appear a little confuſed, becauſe the ſeveral Pencils of Rays that come therefrom, fall too obliquely on the Cryſtalline to be accurately collected in ſo many diſtinct Points of the *Retina*; tho' it muſt be acknowledged, that this Confuſion will, for the moſt Part, be ſo ſmall as to eſcape unobſerved.

§ 25. *Thirdly*, This Diſeaſe may proceed from an oblique Poſition of the Cryſtalline, as in *Fig.* 16. PLATE II. where the Rays that come directly to the Eye from an Object at A, and that ought to converge to the Point of the *Retina* D, which is in the *Axis* of the Eye D E, are, by Reaſon of the Obliquity of the Cryſtalline, made to converge to another Point, as C, on that Side of the viſual *Axis* D E A, where the Cryſtalline is moſt elevated; and therefore the Object is but obſcurely ſeen, becauſe its Image falls not on the *Retina* at

the *Axis* of the Eye, where it is most sensible: But the Rays that fall obliquely on the Eye, as those that come from an Object at B, will, after Refraction, converge to this most sensible Part of the *Retina* D, and, by converging there, must impress the Mind with a clearer Idea of the Object from whence they came. It is for this Reason that the Eye never moves uniformly with the other, but turns away from the Object it would view, being attentive to the Object to which it is not directed. When this is the Case, it is in vain to expect any good from Medicine.

The Symptoms that naturally arise from it are, 1*mo*, The Object A, to which the Eye is directed, will be but faintly seen, because its Image falls on the *Retina* at C, where it is not very sensible.

2*do*, The Object B, to which the Eye is not directed, by having its Image painted on the *Retina* at the *Axis* of the Eye D E, will be clearly perceived. But,

3*tio*, This same Object B must appear somewhat indistinct, because the Pencils of Rays that flow from it are not accurately collected in so many distinct Points in the *Retina*, by Reason of their oblique Incidence on the Crystalline. And,

4*to*, It must be seen, not in its proper Place B, but thence translated to some other Place,

as

as A, ſituated in the *Axis* of Viſion DEA. (See the preceeding *Lemma* and *Scholium.*) And,

*5to,* Being thus tranſlated from its true Place, where it is ſeen by the other Eye that does not ſquint, it muſt neceſſarily appear double, and the Diſtance between the Places of its Appearance will be ſtill greater, if the Cryſtalline of the other Eye incline to the contrary Side.

Had Monſ. *de la* HIRE attended to this Tranſlation and double Appearance of the Object, I ſee not how he could have imagined, that, when the Cryſtalline is inclined differently in both Eyes, the Moon, for Example, will appear like two Ovals that decuſſate one another, as in *Fig.* 17. PLATE II. (See his *Diſſertation ſur les differens Accidens de la Veüe*); for tho' the Moon, or any round Body, may appear a little oval, from the unequal Refraction of the Rays in the oblique Cryſtalline; and tho' theſe Ovals may have different Inclinations, ariſing from the different Inclinations of the Cryſtallines, yet they can never decuſſate one another; but being tranſlated to two different Places, muſt neceſſarily appear double, and at a Diſtance from each other.

§ 26. *Fourthly,* This Diſeaſe may ariſe from an oblique Poſition of the *Cornea*; which, as MAITRE-JEAN obſerves, in this Caſe, is generally

generally more arched and prominent than what it is naturally.

When the Eye has this Conformation, no Object to which it is directed can be clearly ſeen, becauſe its Image falls not on the *Retina* at the *Axis* of the Eye; and therefore the Eye turns aſide from the Object it would view, that its Image may fall on the moſt ſenſible Part of the *Retina*.

To determine the Situation of the Eye with reſpect to the Object it would view, let AGK be the *Axis* of Viſion, (See *Fig.* 18. PLATE II.), and let the Arch *b*G*d*, whoſe Centre is *o*, repreſent the oblique prominent *Cornea*, and let *a*A*x* be a Cone of Rays, having its *Baſis* in the Pupil, and its *Apex* in the moſt ſenſible Part of the *Retina*; it is evident, that this Cone muſt come from a Point without the Eye, which, of all others, appears moſt clear and diſtinct. To find therefore the Situation of this Point, nothing is required but to trace back the middle Ray AG, in the Line it deſcribed before its Incidence on the *Cornea* at G.

For this Purpoſe, erect upon the Surface of the *Cornea*, from the Point of Incidence G, the Perpendicular GP, and having produced it downwards to Q, from A let fall upon it the Perpendicular AD, and produce it to H, ſo that DH may be to AD, as the Sine of Incidence

Incidence to the Sine of Refraction, that is, as 4 to 3; and about the Centre G, with the *Radius* GA, deſcribing a Circle AHP, draw, parallel to the Perpendicular GPQ, the line HE, cutting the Circumference in E, and join EG: This Line EG ſhall be the Line of the incident Ray, in which an Object muſt be placed to have its Image painted on the *Retina* at the *Axis* of the Eye A, where it is moſt ſenſible. For, if EF be let fall perpendicularly on the Line PQ, this Line EF ſhall be the Sine of Incidence of the Ray EG, the Angle of Incidence being EGP; and this Sine EF is equal to DH; and conſequently in proportion to the Sine of Refraction AD, as 4 to 3.

When the *Strabiſmus* proceeds from this Cauſe, the Prognoſtic and the *Phænomena* that attend it, will be much the ſame as in the Caſe immediately preceeding; from which nevertheleſs it may be diſtinguiſhed by the Obliquity of the *Cornea*, which is manifeſt to the Senſes; and if the *Cornea* be alſo more arched and prominent than what it is naturally, which is commonly the Caſe, the Eye will alſo be ſhort-ſighted.

§ 27. *Fifthly*, This Want of Uniformity in the Motions of our Eyes, may ariſe from a Defect, or any great Weakneſs or Imperfection in the Sight of both or either of the Eyes; and

and this, ſo far as I have obſerved, is the moſt common Cauſe of this Diſeaſe.

It has already been made appear, that the Motions of our Eyes are voluntary and depending upon our Mind, which, being a wiſe Agent, does will them to move uniformly, not from any abſolute Neceſſity in the Thing itſelf, or for want of Power to move them differently, but becauſe of the Utility and Advantage that ariſes from ſuch Motions. Hence Children, for ſome Time after Birth, may be obſerved to look differently with both Eyes, till, from the Advantage they find in moving them the ſame Way, they come at length to move them always uniformly; which uniform Motion does at laſt become ſo neceſſary, as to render any other Motion impoſſible; it being certain, that Cuſtom and Habit does render many Actions neceſſary, which are not eſſentially ſo.

This being the Caſe with Reſpect to the uniform Motion of our Eyes, it follows, that, when the Sight of both, or either of the Eyes, is ſo defective, weak or imperfect, as to diſappoint us of the Advantages that naturally ariſe from their uniform Motion, the Mind will not accuſtom itſelf to this Sort of Motion, but will preſerve its natural and connate Liberty of moving them differently. An Example of this may be had in thoſe, who, from a Cataract,

Cataract, or *Gutta Serena*, have been blind from the Birth, in both or either of their Eyes; and that the ſame Thing may alſo happen, when the Diſeaſe is of a later Date, ſeems evident from what PLEMPIUS obſerves, (*Ophthalmograph. lib.* iv. *Problem.* 13.) of a Girl, who became blind from a *Gutta Serena* in the 5th Year of her Age. This Girl, finding no further Advantage after being blind, in moving her Eyes the ſame Way, came at laſt to forget the Habit ſhe had formerly acquired in the four Years ſhe ſaw, and moved her Eyes differently, ſometimes their *Axes* being parallel, ſometimes converging, and at other times diverging.

The Prognoſtic in this Caſe is the ſame with that of the Diſeaſe from which it proceeds, and the *Phænomena* are ſo obvious from what has been already ſaid, that, to ſay any more, would be but to make Repetitions.

§ 28. *Sixthly*, Another Cauſe from which the *Strabiſmus* may proceed, lies in the Muſcles that move the Eye. When any of thoſe Muſcles are too ſhort or too long, too tenſe or too lax, or are ſeized with a Spaſm or *Paralyſis*, their *Equilibrium* will be deſtroyed, and the Eye will be turned towards, or from that Side where the Muſcles are faulty.

In this Caſe, the Diſeaſe frequently yields to Medicine; and therefore admits of a favourable Prognoſtic,

Prognoſtic, excepting only, when, by a Fault in the firſt Conformation, any of the Muſcles are longer or ſhorter than their Antagoniſt; in which Caſe, if ever it ſhould happen, no Medicine can be of any Value.

As to what concerns the optical *Phænomena*, they are the ſame here as in Caſe *firſt*; only when the Diſeaſe commences not till, by Cuſtom and Habit, the uniform Motion of the Eyes has been rendered neceſſary, all Objects do for ſome Time appear double; of which we have given ſome Examples above; but in Time they appear ſingle, for the Reaſons already explained.

§ 29. *Laſtly*, This Want of Uniformity in the Motions of our Eyes, may proceed from a preternatural Adheſion or Attachment to the Eye-lids: Of this we have already given an Example from LANGIUS; and that the ſame Thing may alſo be occaſioned by a Tumour of any Kind within the Orbit, preſſing the Eye aſide, and reſtraining it from following the Motions of the other, is ſo evident, that I need not bring Inſtances to prove it; thoſe who deſire ſuch, may conſult Obſervators. Here alſo the Caſe may admit of a favourable Prognoſtic; and, as for what concerns the optical *Phænomena*, they muſt be the ſame as in the Caſe immediately preceeding.

CHAP.

## CHAP. II.

### *Of the erect Appearance of Objects.*

SECT I. IN explaining the Manner of Vision, and the Action of the Humours of the Eye, it was demonstrated, that the Images of visual Objects are painted on the *Retina* in an inverted Order; that is, the upper Part of the Object makes the lower Part of the Picture, and the Right-side of the Object makes the Left-side of the Picture, and so of the other Parts. This gives occasion to the Question now before us, How we come to judge rightly of the erect Position of Objects, since their Pictures on the *Retina* are always inverted?

§ 2. To this I answer, That the Mind never sees any Picture painted on the *Retina*, and consequently never judges of the Object from what it observes in this Picture; for it has already been proved, that all our Sensations are present with the Mind and in the *Sensorium*; and that, in seeing any Object, the Mind, by virtue of a connate immutable Law, to which it has always been subjected, traces back its own

Senſation from the *Senſorium* to the *Retina*, and from thence outwards, along Right-lines drawn perpendicularly from every Point of the *Retina*, on which any Impreſſion is made by the Rays forming the Picture, towards the Object itſelf; by which Means the Mind or viſive Faculty does always ſee every Point of the Object, not in the *Senſorium* or *Retina*, but without the Eye in theſe perpendicular Lines: But theſe perpendicular Lines do nearly coincide with the *Axes* of the ſeveral Pencils of Rays that flow to the Eye from the ſeveral Points of the Object, and ſince the Mind has alſo a Power of judging rightly of the Diſtance of Objects, it from thence follows, that every Point of the Object muſt appear, and be ſeen in the Place where it is; and conſequently the Object itſelf muſt appear in its true erect Poſition, notwithſtanding its Picture on the *Retina* is inverted. This I had occaſion to ſay ſomething of before; and therefore I need not enlarge further on it in this Place.

CHAP.

## CHAP. III.

### *Of the Colour of Objects.*

SECT. 1. THE third *Phænomenon* of Vision which we muſt examine, is the Colour of Bodies. About which there have been a great many different Opinions.

The *Peripatetics* affirm, that Colours are real Qualities inherent in the coloured Bodies, and ſuppoſe that Light doth only diſcover them, and render them viſible, but not any ways produce them.

PLATO thought Colour to be a kind of Flame, conſiſting of moſt minute Particles, very congruous to the Pores of the Eye, and darted againſt it from the Object; and ſome Moderns will have Colour to be a kind internal Light of the more lucid Parts of the Object, darkened, and conſequently altered, by the various Mixtures of the leſs luminous Parts.

Others, as did ſome of the antient Atomiſts, maintain Colour not to be a lucid Stream of reflected Light, but a corporeal *Effluvium* iſſuing out of the coloured Body.

Others

Others again account for all Colours, out of the various Mixture of Light and Darkneſs: And the Chymiſts ſometimes will have it ariſe from the Sulphur, and ſometimes from the Salt that is in Bodies; and ſome alſo will have it to proceed from the third Hypoſtatic Principle, *Mercury*.

The *Carteſians*, who make the Senſation of Light to be the Impulſe made on the Eye by certain ſolid, but very minute Globules eaſily permeating the Pores of the Air, and other diaphanous Bodies; theſe, I ſay, derive Colours from the various Proportion of the direct Progreſs or Motion of theſe Globules to their Circumrotation or Motion round their own Centres; by which Means they are qualified to ſtrike the optic Nerves after diſtinct and divers Manners, and ſo do produce the Perception of various Colours.

Dr. Hook, in his *Micrographia*, ſays, the Phantaſm of Colour is cauſed by the Senſation of the oblique or uneven Pulſe of Light; and that this is capable of no more Varieties than two, which ariſe from the two Sides of the oblique Pulſe; ſo that, with him, there is in Reality but two ſimple Colours in the World, *viz.* Red and Blue. Red, ſays he, is an Impreſſion on the *Retina*, made by an oblique and confuſed Pulſe of Light, whoſe ſtrongeſt Part preceeds, and its weakeſt follows: And Blue, he ſays,

ſays, is an Impreſſion on the *Retina* made by an oblique and confuſed Pulſe of Light, whoſe weakeſt Part preceeds, and its ſtrongeſt follows: From the Mixture of which two Colours, and a due Proportion of Black and White (that is, Darkneſs and Light,) he ſuppoſes all other Colours may be produced.

In the *Memoirs of the Royal Academy of Sciences*, there is an Account of a Theory of Light and Colours, which was ſtarted by Father MALEBRANCHE. He thinks, that they ariſe from Vibrations of the minute and inſenſible Parts of Bodies, as Sounds do; and therefore, according to the Degree of the Rapidity of the Motion of the Parts of the luminous Body, it will appear enlightened more or leſs; and, in leſſer Degrees of ſuch vibrating Motions, it will appear not luminous, but of ſuch and ſuch a Colour. But thoſe who are curious, and deſire further Satisfaction in theſe ſeveral Hypotheſes, invented for explaining the Nature and Variety of Colours, muſt have Recourſe to the Authors themſelves; for it is impoſſible to put them in a full good Light, without taking up too much Time; which we are unwilling to do, eſpecially that now they are all rejected as erroneous.

§ 2. That we may therefore give ſome better Account of the Colours of Bodies than theſe

juſt

juſt now mentioned, it muſt be obſerved, that Colours may be conſidered five ſeveral Ways:

1*mo*, They may be conſidered as Properties inherent in the Light itſelf.

2*do*, As Qualities reſiding in the Body that is ſaid to be ſo and ſo coloured.

3*tio*, Colours may be conſidered as the Paſſion of our Organ of Sight, or, which is the ſame Thing, the Agitation of the Fibres of the *Retina* by the Impulſe or Stroke received from the Light, which Agitation is communicated to the *Senſorium* where the Mind reſides, elſe it could perceive nothing.

4*to*, They may be conſidered as the Paſſion, Senſation or Perception of the Mind itſelf, that is, the Idea excited therein by the Agitation of our Organs. And,

5*to*, Colours may be conſidered as the Judgment which our Mind forms when it concludes, that that which feels or perceives is in the Body itſelf ſaid to be coloured, and not in the Mind.

Theſe five Things, as is eaſy to ſee, are very different, and yet they are frequently confounded, as if they were one and the ſame Thing, tho' it is evident, that no Body can talk intelligibly either of Colours, or of any of our other Senſations, without diſtinguiſhing them carefully.

carefully. I ſhall therefore Diſcourſe ſeparately of all theſe Particulars.

And *Firſt*, Of Colours conſidered as Properties inherent in the Light itſelf.

What theſe Properties are, I have before obſerved, was, in the Year 1666, firſt diſcovered by the incomparable NEWTON, and afterwards publiſhed in the *Philoſophical Tranſactions*, where he alſo gave a Specimen of the Experiments he made for confirming his Doctrine. After that, in the Year 1704, the ſame great Man propoſed the ſame Doctrine more fully in his beautiful Treatiſe of Optics, and confirmed it with great Variety of convincing Experiments; where he has demonſtrated, that Light is not all ſimilar and homogeneal, but compounded of Hetrogeneal and diſſimilar Rays, each of which are endowed with different Properties, ſome at like Incidence being more refrangible, and others leſs refrangible; and thoſe that are moſt refrangible, are alſo moſt reflexible, and according as they differ in Refrangibility or Reflexibility, they are endowed with a Power of exciting different Motions or Agitations in our *Retina*; which being propagated thro' the Nerves to the *Senſorium*, give us thoſe different Ideas which we call *Colours:* For to the ſame Degree of Refrangibility ever belongs the ſame Colour, and to the ſame Colour ever belongs the ſame Degree of Refrangibility.

The

The leaſt refrangible Rays are diſpoſed to exhibit a red Colour, and no other; and contrarily, thoſe Rays which are diſpoſed to exhibit a red Colour, are all the leaſt refrangible: The moſt refrangible Rays are all diſpoſed to exhibit a deep violet Colour, and no other; and contrarily, thoſe that are apt to exhibit ſuch a violet Colour, are all the moſt refrangible: And ſo all the intermediate ſimple priſmatic Colours, Indigo, Blue, Green, Yellow, Orange, belong to intermediate Degrees of Refrangibility. And this Analogy betwixt Colours and Refrangibility is very preciſe and ſtrict, the Rays either exactly agreeing in both, or proportionally differing in both. Colours, therefore, conſidered as Properties of Light, are not Modes or Qualifications of Light derived from the various Terminations of Light and Shadow, or from Refractions or Reflections of natural Bodies, as was the general Opinion of former Philoſophers, but original connate and immutable Properties, which, in divers Rays, are divers; ſome Rays, when alone, being of ſuch a Magnitude and Solidity, as diſpoſes them, by ſtriking the *Retina*, to exhibit a red Colour, and no other; ſome an Orange, and no other; and ſome a Yellow, and no other; and ſo of the reſt of the ſimple Colours, Green, Blue, Indigo and Violet. But when they are mixed

mixed and blended promiſcuouſly, they exhibit compound Colours of different Sorts, according as the Light is compoſed of more or fewer of the different coloured Rays, or as they are mixed in various Proportions.

§ 3. The *ſecond* Way how Colours may be conſidered is, as they are Qualities reſiding in the Body that is ſaid to be of ſuch or ſuch a Colour; and, in this Senſe, Colours are nothing but the various Diſpoſitions of the Surfaces of Objects, whereby they are qualified to reflect the Rays of one Sort of Colour in greater Plenty than the other Colours, and, upon that Account, the Objects appear of this or that Colour.

Thus *Minium*, and other Red Bodies, reflect the red Rays moſt copiouſly, and thence appear red; Violets, and all other Bodies of the like Colour, reflect the violet Rays in greater Abundance than the reſt, and thence have their Colour; and ſo of other Bodies, every Body reflecting the Rays of its own Colour more copiouſly than the reſt, and deriving its Colour from the Exceſs and Predominancy of thoſe Rays in the reflected Light: For tho' all Bodies appear of the ſame Colour when placed together in the Light of any one Colour, yet every Body looks more ſplendid and luminous in the Light of its

own Colour than in that of any other; which puts it past Dispute, that every Body reflects the Rays of its own Colour in greater Abundance than it does the rest, and thence has its Colour.

As natural Bodies appear of divers Colours, according as they are disposed to reflect most copiously the Rays originally endowed with those Colours, so, from the different Proportions which the predominant Rays bear to the rest of the reflected Light, arise different Shades or Degrees of those Colours. Where the predominant Rays are very numerous in proportion to the rest, the Colour appears strong and full; but as the Excess of the predominant Rays lessens, the Colour from the Mixture of the other Rays abates of its Liveliness, and becomes more faint and dilute; and when all the Rays are equally reflected, so as that no one Kind predominates, the Colour becomes white; for Whiteness, as I have before observed, is a Mixture of all the Colours; and it is more or less intense, in proportion as the reflected Rays are more or fewer in Number. All Greys, Duns, Russets, Browns, and other dark and dirty Colours, down to the deepest Black, being but so many lesser Degrees of White, and differ from perfect Whites on no other Account, but that they consist of a lesser Quantity of Light, and consequently appear less glaring and luminous.

§ 4.

§ 4. Now, the Reaſon why Bodies reflect this or that Kind of Ray more copiouſly than the Reſt, and conſequently appear of this or that Colour, depends altogether on the Size and Denſity of the Particles of which the Bodies are compoſed; Particles of coloured Bodies reflecting Rays of different Colours according to their different Magnitudes and Denſities, as has been fully proved by Sir ISAAC NEWTON, from Experiments and Obſervations made on the Colours of thinned Bodies of Air, Water and Glaſs; by the Help of which, he has, in the ſecond Book of his Optics, given us a Table containing ſeven Orders or Series of Colours, together with the Thickneſſes of the Particles of Air, Water and Glaſs, which exhibit the ſeveral Colours in each Order; which Thickneſſes are expreſſed in Parts, whereof ten hundred Thouſand make an Inch. The firſt Part of that Table is here laid before you, and, by Inſpection thereof, it will be found, that, in each Order of Colours, the Red is reflected by Particles of the greateſt Thickneſs, and that the Thickneſſes of the Particles which reflect the other Colours, grow leſs and leſs, as the Colours which they reflect are more and more removed from the Red. It is likewiſe manifeſt, from the ſame Table, that, among the Particles which reflect one and the ſame Colour, thoſe which have

have the greateſt Denſity, have the leaſt Thickneſs. Thus, for Inſtance, the Thickneſs of a Particle of Glaſs, which reflects the Scarlet of the ſecond Order, is but $12\frac{2}{3}$; whereas, the Thickneſs of Water, which reflects the ſame Colour, is $14\frac{3}{4}$, and that of Air ſtill greater, to wit, $19\frac{1}{3}$: So that the Thickneſſes of the Particles which reflect any Colour increaſe as their Denſities leſſen; for which Reaſon, Particles of the ſame Thickneſs may reflect different Colours, provided their Denſities be unequal. Thus the Particles of Air, which reflect the Violet of the ſecond Order, have very nearly the ſame Thickneſs with Particles of Water, which reflect the Green, as alſo with the Particles of Glaſs, which reflect the Orange of the ſame Order.

| Their Colours of the firſt Order. | *Thickneſſes of* Air. | Water. | Glaſs. |
|---|---|---|---|
| Very Black | $\frac{1}{2}$ | $\frac{3}{8}$ | $\frac{10}{31}$ |
| Black | 1 | $\frac{3}{4}$ | $\frac{20}{31}$ |
| Beginning of Black | 2 | $1\frac{1}{2}$ | $1\frac{2}{7}$ |
| Blue | $2\frac{2}{5}$ | $1\frac{4}{5}$ | $1\frac{11}{20}$ |
| White | $5\frac{1}{4}$ | $3\frac{7}{8}$ | $3\frac{2}{5}$ |
| Yellow | $7\frac{1}{9}$ | $5\frac{1}{3}$ | $4\frac{3}{5}$ |
| Orange | 8 | 6 | $5\frac{1}{6}$ |
| Red | 9 | $6\frac{3}{4}$ | $5\frac{4}{5}$ |

| | | *Thickneſſes of* | | |
|---|---|---|---|---|
| | | Air. | Water. | Glaſs. |
| Of the ſecond Order. | Violet | $11\frac{1}{6}$ | $8\frac{3}{8}$ | $7\frac{1}{5}$ |
| | Indigo | $12\frac{5}{6}$ | $9\frac{5}{8}$ | $8\frac{2}{11}$ |
| | Blue | 14 | $10\frac{1}{2}$ | 9 |
| | Green | $15\frac{1}{8}$ | $11\frac{1}{3}$ | $9\frac{5}{7}$ |
| | Yellow | $16\frac{2}{7}$ | $12\frac{1}{5}$ | $10\frac{2}{5}$ |
| | Orange | $17\frac{2}{9}$ | 13 | $11\frac{1}{9}$ |
| | Bright Red | $18\frac{1}{3}$ | $13\frac{3}{4}$ | $11\frac{5}{6}$ |
| | Scarlet | $19\frac{2}{3}$ | $14\frac{3}{4}$ | $12\frac{2}{3}$ |

From what has been ſaid concerning the Colours of natural Bodies, conſidered as belonging to the Object, it follows, that, if any Change be made in the Size or Denſity of the Particles whereof a Body is compoſed, the Colour of the Body will likewiſe be changed; for which Reaſon, if two colourleſs Liquors be mixed together, they may, in mixing, ſuffer ſuch Changes in the Size and Denſity of their Parts, from their mutual Actions one upon another, as to become opaque and coloured; and ſuch Liquors as are coloured may, for the ſame Reaſon, when mixed together, either become tranſparent and colourleſs, or of ſuch a Colour as is different from the Colour of either, before the Mixture. But we muſt remit thoſe, who deſire full Satisfaction in this and the foregoing Point, to that admirable Treatiſe of Optics written

written by NEWTON; for it is impoſſible to ſeparate the Parts of this Work from one another, without Diſadvantage to them, or to ſum them up in leſs Room, without loſing many Things, as true and uſeful, as they are beautiful and entertaining: That great Man having before ſhewn, how far Numbers in Geometry would go in natural Philoſophy, has, in his Optics, manifeſted to the World to what ſurprizing Height even vulgar Experiments, duly managed and carefully examined, in ſuch Hands, may advance it.

§ 5. The *third* Manner in which Colours may be conſidered, is the Paſſion of our Organ of Sight, that is, the Motions or Vibrations excited in the Fibres of the *Retina* by the Impulſe or Stroke received from the Rays of Light; which Motions or Vibrations being propagated along the ſolid Fibres of the Optic Nerves into the Brain, cauſe the Senſation of Colours. For the Rays of Light being Corpuſcles of different Magnitudes, will, by ſtriking the *Retina*, excite Vibrations of different Bigneſſes, which, according to their Bigneſſes, muſt excite Senſations of ſeveral Colours, much after the Manner that the Vibrations of the Air, according to their ſeveral Bigneſſes, excite Senſations of ſeveral Sounds; and particularly the ſmalleſt or moſt refrangible Rays will excite the ſhorteſt and weakeſt Vibrations for making

king a Senſation of deep Violet, the largeſt or leaſt refrangible Rays, the largeſt and ſtrongeſt Vibrations for making a Senſation of deep Red, and the ſeveral intermediate Sorts of Rays, Vibrations of ſeveral intermediate Bigneſſes, to make Senſations of the ſeveral intermediate priſmatic Colours; but when the ſeveral Heterogeneal Rays are blended together promiſcuouſly, they muſt then, in falling upon the *Retina*, excite ſeveral other different Sorts of Vibrations, for making the Senſations of the ſeveral compound Colours; which will therefore differ among themſelves, according as the Light is compoſed of more or fewer of the different coloured Rays, or as they are mixed in various Proportions.

§ 6. From this it is eaſy to ſee, how it comes to paſs, that, when a Man in the Dark preſſes either Corner of his Eye with his Finger, and turns his Eye away from his Finger, he will ſee a Circle of fiery Colours like thoſe in the Feather of a Peacock's Tail. If the Eye and the Finger remain quiet, theſe Colours vaniſh in a ſecond Minute of Time; but if the Finger be moved with a quivering Motion, they appear again. Theſe Colours can ariſe from nothing but ſuch Motions or Agitations excited in the Bottom of the Eye, by the Preſſure and Motion of the Finger, as at other Times

are

are excited there by Light for causing Vision; and they continue about a Second of Time, because the Motions excited in the *Retina*, for causing Vision, do not presently perish, but are of a lasting Nature; and considering the Lastingness of these Motions, they are reasonably thought to be of a vibrating Nature.

And not unlike this, is also the Appearance of Fire, which happens when a Man receives a stroke upon his Eyes; for the Motion excited in the *Retina* by such a Stroke, being similar to that which at other Times is excited by Fire, the Mind will receive the same Sensation, and consequently must be made to perceive a Flash of Light, as every body hath experienced.

These apparent Colours are not only seen when the *Retina* suffers any Motion or Agitation, like what at other Times are excited by Light coming from Objects; for a similar Agitation in the *Sensorium* or Origin of the Nerves alone, is also sufficient to give us those Ideas:

We have daily Examples of this in Fevers, when the delirious Patient imagines he sees, hears and feels Objects, which not being present, cannot act upon the Organs of Sense: But, in this and such like Diseases, the State of the Brain is such, that the Impressions made upon the *Sensorium* by the circulating Fluids, are

are so lively, and so much a-kin to what at other Times are excited there by Light coming from Objects, that it is impossible to persuade them, that they are in an Error. Neither needs this be any way surprising; for none of our Sensations proceed from the Motions excited in our Organs, but in so far as they are communicated to the *Sensorium* or Origin of the Nerves; and therefore, when such Motions are excited in the *Sensorium*, as at other Times are excited there by Objects acting on the Organs, the Mind must have the same Perception, and must form the same Judgment concerning it, as if the Object itself were present, and acted on the Organs; for the Mind never knows what passes in the Organs, but only judges according to what passes in the *Sensorium*, where it has its Residence. And this is the only rational Account can be given of these delirious Imaginations, which happen in Fevers and other Diseases.

§. 7. Before I leave this Subject, it may not be improper to take notice of a very gross, tho' vulgar Error, into which the greatest Part of Mankind fall, when they imagine that every Body has the same Sensation of the same Object: As for Instance, we are ready to believe that every body sees Snow white, the Heavens blue, the Meadows green, and all other visible Objects after the same Manner we see them. Many, no doubt, will wonder, how I come thus to doubt of Things which are believed e-

vident. Nevertheleſs, it is certain, that there is no Manner of Reaſon for our thinking ſo; and tho' we cannot demonſtrate mathematically that we are deceived, when we think that all the World ſee Objects after the ſame Manner that we do, yet we can clearly demonſtrate, that, if we are not deceived, it is by the greateſt good Chance in the World; and even there are not wanting ſeveral Reaſons ſtrong enough to convince us of our Error.

For to be perſuaded of the Truth of what I have advanced, w emuſt obſerve, that there is a great Difference betwixt our Senſations and the Cauſe of our Senſations. The Cauſe of our Senſations conſiſts in nothing but certain Motions or Agitations excited in our Organs, and thence propagated to that Part of the Brain in which the Mind reſides; but our Senſations themſelves, or that which every one feels when he perceives an Object, are the Modifications of the Mind itſelf; which have nothing in common with the Motions in the Body to which they are connected; as for Inſtance, there is no neceſſary Connection betwixt any particular Colour, Taſte, Smell or Sound, and the particular Motion in the Organs by which they are ſaid to be excited; and therefore it is poſſible, that ſimilar or like Motions in the optic Nerve of different Perſons, may not give them the ſame Sort of Senſation, that is, make them ſee the ſame Colour.

Thus,

Thus the Motion which cauſes Redneſs in one, may cauſe the Senſation of green or blue in another, or even ſome other new Senſation, which no body before has ever felt or dreamed of.

All this is at leaſt poſſible; neither are there any Arguments, by which the contrary can be proven: Yet we cannot but own, that it is not probable; for it is reaſonable to believe, that Nature acts always after the ſame Manner in the Union which it has fixed betwixt our Minds and Bodies; and that it has connected the ſame Ideas and Senſations to the ſame Sort of Motions excited in the Organs and *Senſorium* of different Perſons. But then, ſuppoſing this true, and that the ſame Motions or Agitations excited in the Organs and *Senſorium* are in every body always accompanied with the ſame Sort of Senſations, it follows, that, if the ſame Object does not produce the ſame Motion in the Organs of different perſons, it will not excite the ſame Senſation in their Mind.

But it is evident, that the Organs of Senſe, which, in different Perſons, are differently diſpoſed, cannot receive the ſame Impreſſions from the ſame Object; and therefore, when theſe different Impreſſions are tranſmitted to the Brain, the Mind muſt receive different Senſations: As for Inſtance, the Blows which Porters

ters and Seamen do give themſelves for warming them when cold, would hurt, pain, and even maim others, whoſe Bodies and Organs are more tender and delicate; the ſame Stroke does therefore produce different Motions, and conſequently excites different Senſations in a Man of a firm robuſt Conſtitution, and in a Child or Woman of a weak, ſoft and delicate Complection. And thus you ſee, that ſince there are not two Men in the World, of whom we are certain that they have their Organs of Senſe in a perfect Conformity, we can never be certain that there are two Men in the World, that have the ſame Senſation of the ſame Object.

It is from this, that *that* ſtrange Variety, to be found in the Inclinations of Men, does proceed. Some are paſſionate Lovers of Muſic, others are intirely inſenſible of its Charms; and, even among thoſe that delight therein, ſome like one Sort of Muſic, others another; according to the different Diſpoſitions of their auditory Nerves, Blood, and Spirits. And what we have ſaid of Muſic and Sounds, does alſo take place in Smells: Some admire the Smell of Orange and Jeſſamine Flowers, who cannot bear that of the Roſe; others are charmed with the Smell of Roſes, and abhor that of the Orange. As for Taſtes, there is as great a Variety, as in any other Senſation; Sauces muſt be altogether different for to pleaſe

equally

equally different Perſons, and to pleaſe equally the ſame Perſon at different Times; one likes what is ſweet, and another what is ſour; one loves the Taſte of Wine, another nauſeates it; and even the ſame Perſon who thinks it agreeable when in Health, thinks it is deteſtable when in a Fever. And the ſame Thing holds true in the other Senſes: But every Body loves Pleaſure; they love all the agreeable Senſations; in this they have all the ſame Inclination; and therefore it is evident, that they do not receive the ſame Senſation from the ſame Object, ſince they do not all equally love it. Thus, when a Man ſays, he likes what is ſweet, this is becauſe the Senſation thereof is agreeable to him; and when another ſays he likes not what is ſweet, this happens becauſe he has not the ſame Senſation with the other that likes it; and therefore, when he ſays, he likes not what is ſweet, we are not to underſtand that he likes not to have the ſame Senſation with the other, but only that he has it not: So that we ſpeak improperly, when we ſay, that he likes not what is ſweet; we ought to ſay, that he likes not Sugar or Honey, which every Body elſe feels ſweet and agreeable, and which he feels otherwiſe, becauſe the nervous Fibres of his Tongue are otherwiſe diſpoſed.

But, to render this Matter ſtill more clear and evident, I ſhall illuſtrate it by an Example that

that is more ſenſible. Suppoſe then that, of ſix Perſons, there are ſome whoſe Hands are extremely cold, and who are ignorant of the Names uſed by us in *Britain* to expreſs the Senſations of Cold, and Heat; and, on the contrary, ſuppoſe that the Reſt have their Hands extremely hot; if a Baſon of ordinary Water be brought them for waſhing their Hands, thoſe whoſe Hands are very warm, as ſoon as they begin to waſh, will feel the Water extremely cold, becauſe vaſtly colder than their hot Hands; and therefore may ſay, that *that* Water is exceeding cold, I do not like it; but the Reſt, that are ignorant of the Words *Cold* and *Heat*, and whoſe Hands are exceſſively cold, when they come to waſh, will, on the contrary, ſay, I am ſurpriſed you like not cold, for my Part I take pleaſure in cold Water, and am delighted therewith to waſh my Hands.

It is very evident, in this Example, that when thoſe laſt named Perſons ſay, they like Cold, nothing is to be underſtood, but that they like Heat; and in like Manner, when one ſays, he likes what is bitter, and cannot bear Sweetneſs, no more is meant, than that he has not the ſame Senſation with thoſe that ſay, they like what is ſweet, and have an Averſion to every Thing that is bitter; for it is certain, that every Senſation that is agreeable

to

to one, is likewiſe ſo to all who feel it; but becauſe of the different Diſpoſitions of the Organs of Senſe, it is not always perceived from the ſame Object. And this I take to be of great Conſequence to be obſerved for Morals, as well as for Phyſics.

Now, all theſe Reaſons, which ſhew that our other Senſations are not alike in different Perſons, do likewiſe ſhew that the ſame Variety ought to obtain in the Senſation of Colours; for it cannot be doubted, but there is as great a Variety in the Diſpoſition of the Organs of Sight in different Perſons, as in thoſe of Taſte, Hearing, *&c.* and therefore we may ſafely conclude, that every body does not ſee the ſame Colour in the ſame Object. And this is the Reaſon why the ſame Colour does not equally pleaſe; ſome like one, others another, which would never happen, were the Senſations of Colour the ſame in all. I have heard of ſome who were always made uneaſy by the Sight of green Colours, tho' ſuch Colours are agreeable to moſt others. BOYLE alſo, in his Obſervations upon vitiated Sight, gives ſome Inſtances of Colours appearing different from what they appeared to others, whoſe Eyes were ſound.

But, beſides the Diverſity of Colours that may ariſe in different Perſons, from the various Diſpoſitions of the *Retinæ* and optic Nerves, it is certain, that no leſs a Varie-

ty

ty may proceed from the different Colours with which the Humours of the Eye may be tinged.

Thus, if they be tinged with Red, Orange, Yellow, Green, Blue, Indigo, Violet, *&c.* ſo as to tinge the Pictures in the Bottom of the Eye with theſe Colours, all Objects will ever appear tinged with the ſame Colours; and tho' they are ſeen very diſtinctly when the Tincture does not render the Humours opaque, yet they will appear in the ſame Manner as to an Eye that is perfectly ſound, when it looks at them through a Glaſs, tinged with the like Colours. And that the Humours of the Eye are of various Colours in various Perſons, is evident from many Obſervations; for tho' the aqueous Humour be commonly clear, and in Conſiſtence nearly approaching that of the White of an Egg well agitated into a thin Liquor, yet, in different Ages, both its Colour and Conſiſtence is altered, and in old Age, it is frequently whitiſh; the Cryſtalline alſo changes its Colour, as we advance in Years, inſomuch that Dr. PETIT found, that, in a Man of 81 Years old, it reſembled a Piece of beautiful yellow Amber, as has been before obſerved; and, in the Jaundice, the whole Eye is ſo much tinged with Yellow, that all Objects muſt appear tinged with that Colour, tho' we may be inſenſible of it, unleſs when the Colour is ſtrong and happens

pens ſuddenly, for the Reaſons formerly explained.

§ 8. The *Fourth* Manner in which Colours may be conſidered, is the Paſſion, Senſation or Perception of the Mind itſelf, or that which all of us perceive when we look at any Object.

It is this only that, properly ſpeaking, deſerves the Name of Colour; for Colours in Objects are nothing but their Diſpoſition to reflect this or that Sort of Rays more copiouſly than the reſt, and, in the Rays of Light, they are their Diſpoſition to excite this or that Motion in the Organs of Viſion; and in them they are only different Motions or Vibrations in the Spirits, or rather in NEWTON's ſubtile elaſtic *Æther*, which are propagated thro' the nervous Fibres to the *Senſorium*. In all this, there is no Perception, no Senſation, no Colour; for, to ſpeak truly, Colours are Senſations produced in our Mind, and do not belong either to Light, Objects, our Organs, or any other Body, but are the Modifications of the Mind itſelf, which always ſtand connected to what paſſes in the Organs and *Senſorium*.

§ 9. Many Philoſophers maintain, that we have not any Knowledge of our Senſations, and therefore perplex and puzzle themſelves exceedingly, to find out and explain what

Colours, Pleaſure, Pain, and our other Senſations are, tho' they allow that they are in the Mind, and that they are nothing but its different Modifications.

It is indeed ſurpriſing to ſee thoſe People ſeek to learn what they are not ignorant of; for it is impoſſible they can be ignorant of Colours, Pleaſure or Pain, when they perceive them. Thus, when I burn my Hand, I eaſily diſtinguiſh that Pain which I feel, from Colour, Sound, Taſte, Smell; I diſtinguiſh it from Admiration, Deſire, Love and Hatred; I diſtinguiſh it from a Square, a Circle and Motion: In fine, I find it very different from every thing which is not that preciſe Pain which I feel: How then is it poſſible that I know ſo certainly, that *that* which I feel is none of thoſe other Things, if I had no Knowledge of thoſe Modifications in which our Senſations conſiſt? It is therefore evident, that all of us know what are the Modifications of our Mind, when we ſee Colours, or when we have any other Senſation; for, if we did not know them, it would be impoſſible for us to diſtinguiſh any ſenſible Object: Water and Wine, Black and White, would ever appear the ſame, did we not feel that the Senſation of the one is very different from that of the others.

It is indeed true, that, if any one aſks that I explain theſe Modifications of the Mind,

in

in which Colours, Pleaſure, Pain, and our other Senſations conſiſt, I cannot do it in Words; yet it does not from thence follow, that, when I ſee Colours, or am burnt, I know not what theſe Modifications are, in which theſe Senſations conſiſt.

The Reaſon why Colours, and our other Senſations, cannot be explained by Words, is becauſe Words are only arbitrary Signs of Ideas already perceived; and therefore, if a blind Man aſks me, what I mean by a white, black, or red Body? I can never inform him; becauſe there is no neceſſary Connection betwixt Words and thoſe Ideas of the Mind which we call Colours: It depends intirely on the Will of Man, to connect ſuch Words to ſuch Ideas. When I ſee a white Body, I receive a certain Idea to which I may give any Name I pleaſe; I may, with the *Romans*, call it *Corpus album*, or, with the *French*, *une Corps blanc*; yet there is no neceſſary Connection betwixt the Sound of theſe Words and the coloured Body, of which they are the Signs; and therefore a blind Man, in hearing theſe or any other Words, can never receive the Idea of a white Body. Theſe Ideas are the Modifications of the Mind itſelf, and are only connected to certain Motions excited in the *Retina*, optic Nerve and *Senſorium*, by the Impulſe received from the Rays of Light: It is therefore in vain

vain to seek to explain, by Words, what Colours are, since Words are only the arbitrary Signs of Ideas already received; Colours are not at all attached to Words, or to the Motions excited in the auditory Nerves, but to those excited in the optic Nerves; and therefore, to know what Colours are, we must first open our Eyes, and receive those Impressions upon our Organs of Sight, to which alone, when transmitted to the *Sensorium*, those Modifications of our Mind, which we call Colours, are connected. But to proceed,

§ 10. The *fifth* Manner in which Colours may be considered, is the Judgment which our Mind naturally forms, when it concludes, that *that* which it feels or perceives is in the Body itself said to be coloured, and not in the Mind.

How Body acts upon Mind, or Mind upon Body, I know not; but this I am very certain of, that nothing can act or be acted upon where it is not; and therefore our Mind can never perceive any thing but its own proper Modifications, and the various States and Conditions of the *Sensorium* to which it is present; for, when I look at the Sun or Moon, it is impossible that these Bodies, so far distant from my Mind, can, with any Propriety of Speech, be said to act upon it. To imagine otherwise, is to imagine Things can act where they

they are not present; which is as absurd, as to suppose, that they can be or exist where they are not present. *Nam virtus sine substantia subsistere non potest.* NEWTON *Princip. Mathemat. Schol. general. sub fin.* These Bodies do indeed emit Light, which falling upon the *Retina*, does excite certain Agitations in the *Sensorium:* And it is these Agitations alone which can any way act upon the Mind, and therein excite those Modifications which we call Colours: So that it is not the external Sun or Moon which is in the Heavens, which our Mind perceives, but only their Image or Representation impressed upon the *Sensorium.* How the Soul of a seeing Man sees these Images, or how it receives those Ideas from such Agitations in the *Sensorium*, I know not; but sure I am, it can never perceive the external Bodies themselves, to which it is not present: So that, properly speaking, the Colours which our Mind perceives, when we look at any Object, are only the Modifications of the Mind itself, arising from the Motions excited in the *Sensorium:* And, when we imagine we see these Colours in the external Object itself, this certainly is not a Perception, but a Judgment or Conclusion whereby we attribute that which our Mind feels to external Objects.

§ 11.

§ 11. What we have ſaid with reſpect to Colours, may, without Difficulty, be alſo applied to our other Senſations: For we not only aſcribe the Colours we perceive to the Objects we look at, but alſo we judge that our other Senſations are in the other Objects of Senſe.

Thus, when I taſte Sugar, I conclude it is ſweet, and, when I ſmell Camphire, or ſuch like odoriferous Bodies, I am naturally inclined to look on that ſmell which I perceive as a Quality inherent in the Object; and yet it is certain, that theſe different Senſations are only the Modifications of the Mind itſelf, and do not belong to the Objects, to which they are generally attributed.

§ 12. It is indeed true, that our Mind does not always attribute its own proper Senſations to the external Objects that produce them; for ſometimes it aſcribes them to the Organs, at other times, both to our Organs and the Object.

That we may explain how this happens, we muſt conſider, that the Senſations of our Mind are of three different Sorts; ſome are very ſtrong and lively; others weak and faint; and a third Sort are of a middle Nature betwixt both.

Our ſtrong and lively Senſations, are thoſe that touch our Mind very ſenſibly, and as it were

were ſurpriſe it, and rouze it up with Force and Vigour; and of this Sort are all thoſe Senſations which are very agreeable or painful, ſuch as that which ariſeth when one is tickled with a Feather, or burnt with the Fire, and, in general, when the Organs ſuffer any thing that is capable of hurting or deſtroying the Body: In all theſe Caſes, our Senſations are ſo briſk and lively, that the Mind can ſcarce hinder itſelf from looking on them, as in ſome Sort belonging to itſelf; and therefore it does not judge that they are in the Objects, but believes them to be in the Members of its Body, which, becauſe of the ſtrict Union of Mind and Body, it conſiders as a Part of itſelf. Thus, when my Hand is prickt with a Pin, burnt, or otherwiſe hurt, I am naturally directed to attribute that painful Senſation to that Part of my Hand on which the Impreſſion is made, and not to the Fire, Pin, or other Object producing it; and yet it is certain, that Pain is a Senſation, or Modification of the Mind itſelf, and belongs as little to our Organs, as Colours do to Objects.

The *ſecond* Sort of Senſations are the weak and languiſhing, in which the Mind is but very ſlightly touched, and which are neither very agreeable nor diſagreeable, as Light, when not too ſtrong, all manner of Colours,

Taſtes

Taſtes and Smells, moderate Sounds, *&c.* Theſe Senſations do ſo ſlightly affect our Mind, that it never thinks that they belong to it, nor that they are in the Body to which it is united, but only in the external Objects that produce them. It is for this Reaſon we rob the Mind of its own proper Senſations of Light and Colour, therewith to deck and imbelliſh the Object; and yet there is nothing more evident, than that all of them are the Modifications of the Mind itſelf, and noways inherent in the Objects in which our Mind places them.

The *laſt* Sort of our Senſations are neither ſtrong nor faint, but of a middle Nature betwixt both, ſuch as Heat and Cold, when moderate, great Light, violent Sounds, *&c.* And here it may be obſerved, that a weak and languiſhing Senſation may become both a middle and a ſtrong One; as for Inſtance, the Senſation of Light is weak when the Light of a Candle or Flambeau is faint, or when it is at any conſiderable Diſtance; but this Senſation may become a middle One, if the Flambeau be brought near enough the Eye for to dazzle; and likewiſe it may become very ſtrong and vivid, provided that it be brought ſo near as to burn. Thus, the Senſation of Light may be weak, ſtrong, or betwixt both, according to its different Degrees.

Now,

Now, theſe middle Senſations do neither touch the Mind very ſenſibly, nor very ſlightly: Hence it is, that it is very much embarraſſed and ſtraitened where to place its Senſation; for, upon the one Hand, it is inclined to follow the natural Judgment of the Senſes, in removing from itſelf, as much as poſſible, theſe Sorts of Senſations, to attribute them to the external Objects; but, upon the other Hand, it cannot altogether hinder itſelf from looking on them as in ſome Sort belonging to itſelf, eſpecially if they approach to thoſe which we have called ſtrong and briſk. And this is the Reaſon that the Mind judges, that Cold, Heat, and the other middle Senſations, are not only in the Ice, Fire, and other Objects producing them, but alſo in that Part of the Body itſelf upon which the Impreſſions are made.

Thus, you ſee, how the Mind never conſiders its Senſations as belonging to itſelf, but always attributes them either to the Object, our Organs, or both, according as they are of a ſluggiſh, briſk, or middle Nature; and tho' it is certain, that they are the Modifications of the Mind itſelf, yet, ſince our Senſes are not given us to inform us what Things are in themſelves, but only what they are relatively to our Bodies, it was very neceſſary that they ſhould incline us to judge of ſenſible

Qualities in the Manner they do: As for Inſtance, it is much more profitable for us to feel Pain and Heat, as in our Body, than that we ſhould judge them only in the Objects that cauſed them; for, ſince they are capable of hurting and deſtroying our Members, it was neceſſary that we ſhould be advertiſed, when they are thereby attacked, in order to ſecure ourſelves therefrom: But it is not ſo with reſpect to Colours; for they do not ordinarily hurt the *Retina* on which they fall; and it is altogether uſeleſs for us to know that they are painted there. Colours are not neceſſary, unleſs to know Objects more diſtinctly and at a Diſtance; and it is for this Reaſon, that our Sight ever inclines us to attribute them to Objects. From all which, it is manifeſt, that the Judgments which our Senſes induce us to make concerning the ſenſible Qualities, are exceeding juſt, if conſidered with reſpect to the Preſervation of our Bodies, for which they were only given us; tho', at the ſame Time, it is moſt certain, that they are altogether extravagant, and vaſtly removed from Truth.

CHAP.

## CHAP. IV.

### *Of the Magnitude of Objects.*

THE fourth *Phænomenon* of Viſion is the Extenſion or Magnitude of Objects, which we ſhall now inquire into.

§ 1. What the abſolute Magnitude of Bodies is, we know not; for our Eyes do never inform us, what Extenſion is in itſelf abſolutely conſidered, but only what it is relatively to that of our own Body: For it is certain, that with Microſcopes we may ſee Animals a great deal ſmaller than a Grain of Sand that is almoſt inviſible; even ſome have been ſeen a Thouſand Times leſs. Theſe little living Atoms move and walk, as well as Man and other larger Animals; and therefore muſt have Legs and Feet, Bones in their Legs to ſuſtain their Bodies, Muſcles for moving them, Tendons and a Multitude of Fibres in each Muſcle, and, in fine, they muſt have exceeding ſubtile Blood and Spirits for cauſing their Muſcles to contract: Without this, it would be impoſſible for them to live, move, and perform all thoſe Actions which they are obſerved

obſerved to do: All theſe Parts are ſo very ſmall, that our Imagination is aſtoniſhed, and loſes itſelf in conſidering them; and tho' our Reaſon convinces us of their Exiſtence, yet our Senſes and Imagination oppoſe themſelves thereto, and frequently, by obliging us to doubt thereof, throw us into many Errors.

Our Sight is very much limited; but it ought not to limit its Object. The Idea which it gives us of Extenſion, has very narrow Bounds; but it does not from thence follow, that Extenſion is ſo alſo. It is in a Senſe, without doubt, infinite, and every little Particle of Matter, which, by Reaſon of its Smallneſs, eſcapes our Sight, is capable of containing a World, in which are as many Things, tho' leſs in proportion, as in this great World in which we live.

The little Animals which we have been ſpeaking of, may poſſibly have others vaſtly leſs that feed upon them, and which are imperceptible to them, becauſe of their extreme Smallneſs; juſt as thoſe firſt named Animals are to us: For what theſe little Animals are with reſpect to us, thoſe others will be to them. Neither is it impoſſible, but that there may be in Nature an infinite Series of leſſer and leſſer Animals that bear the ſame Proportion to each other, as that of a Man to a Mite.

We have evident and mathematical Demonſtrations of the Diviſibility of Matter *in infinitum*;

*tum*; and that is ſufficient to convince us, that there may be an infinite Series of ſuch little Animals ſtill leſs and leſs; for GOD hath not made Matter, but to form thereof various and wonderful Works; and ſince we are certain, that there is no Particle whoſe Smallneſs is capable of limiting his Power in the Formation of theſe little Animals, why then ſhould we limit it, and thus, without Reaſon, diminiſh his infinite Power, in meaſuring it by our narrow and confined Imaginations?

Experience has already undeceived us in Part, in making us ſee Animals a Thouſand Times leſs than a Mite; why then ſhould we fancy thoſe the leaſt and ſmalleſt of all? For my Part, I can ſee no Reaſon for thinking ſo; on the contrary, it is much more probable, that there are ſtill Animals a great deal ſmaller than any yet obſerved, and that little Animals are not wanting for Microſcopes, but Microſcopes for theſe little Animals.

It is therefore evident, that our Eyes do not give us Ideas of all thoſe Things which we diſcover by Microſcopes, and by Reaſon. We never obſerve with our Eyes any Thing leſs than a Mite; the Half of a Mite is nothing, if we believe the Teſtimony of our Senſes. Our Eye looks on a Mite as a mathematical Point, which cannot be divided, without being annihilated; whence it follows, that our Sight does

does not repreſent Extenſion to us, ſuch as it is in itſelf, but only the Relation and Proportion it has to our Body; and becauſe the Half of a Mite has no remarkable Proportion to our Body, and can neither hurt it, nor any way contribute to its Preſervation, our Sight hides it intirely from us; but, were our Eyes made like Microſcopes, or were we ourſelves as ſmall as Mites, we ſhould judge very differently of the Magnitude of Bodies: For it is not to be doubted, but theſe little Animals have their Eyes ſo diſpoſed, as to ſee their own Bodies, and the Objects ſurrounding them, a great deal larger than we do; without this, they could never receive the neceſſary Impreſſions from Objects capable of hurting or nouriſhing their Bodies, and conſequently their Eyes would be intirely uſeleſs to them.

§ 2. But, in order to explain this Matter fully, we ought to conſider, that our own Eyes are really no other than a kind of natural Spectacles; that their Humours do the ſame Office as the *Lenſes* of dioptrical Inſtruments; and that, according to the Figure of the *Cornea* and *Chryſtalline*, and their Diſtance from the *Retina*, Objects are ſeen very differently; inſomuch that we are never ſure that there are any two Perſons in the World who ſee them equally big, becauſe we can never be ſure that their Eyes are perfectly alike. It is even very rare, that the ſame Perſon ſees the ſame Object equally

equally big with both Eyes, as both Eyes are very ſeldom perfectly alike; on the contrary, we generally ſee Things bigger with the left than with the Right-eye, of which we have ſome very good Obſervations in the *Journal of the learned at Rome* for the Year 1669. And the learned GASSENDUS tells us, that he himſelf had his Eyes ſo made, that with the one he always ſaw Objects three Times larger than with the other (See *de Chale's Optics*, *Lib.* I. *Prop.* xxxix.) *Pere* MALLEBRANCHE alſo informs us of a Man at *Paris* who ſaw Objects a good deal longer with one of his Eyes than with the other (*Recherche de la Verité*, *Liv.* I. *Chap.* 6.) And if this Difference obtains in the Eyes of the ſame Man, it cannot be doubted, but it may alſo obtain in the Eyes of different Men.

§ 3. Having converſed with ſome of my Friends on this Head, I find, that moſt of them entertain ſome Doubt, whether Objects can be ſeen of different Magnitudes on Account of the different Convexity of the *Cornea* or Cryſtalline; for, having obſerved that the Pictures of Objects formed by a convex *Lens* are always formed under the ſame Angle, of whatever Convexity the *Lens* may be, they ſeem inclined to imagine, that the ſame Thing ſhould alſo take place in the Eye; and that therefore the Object ſhould always appear the ſame, whether the *Cornea* or Cryſtalline be convex

convex or flat. This Reasoning would indeed hold, did the Eye consist but of one Humour; but it will not hold in an Eye formed as ours is, and that has several Humours, whose refractive Powers are different. But, that I may the better remove this Difficulty, I shall demonstrate the following Proposition:

## PROPOSITION.

*The more convex the* Cornea *is, Objects appear the larger.*

DEMONSTRATION. Let AB (*Fig.* 19. PLATE III.) be the *Axis* of the Eye, *a* the Centre of the Crystalline, C the Centre of the *Cornea* in its natural State, which Centre, according to PETIT's Measures of the Eye, falls a considerable Way behind the Crystalline, as in the Figure, *c* the Centre of a more convex *Cornea*, *a* the Centre of another *Cornea* yet more convex, which Centre coincides with the Centre of the Crystalline, PB a Picture formed on the *Retina*, P the extreme Point of this Picture, *m*P*n* the Cone of Rays forming the Point P of the Picture, P*ax* the *Axis* of that Cone or Pencil passing thro' *a* the Centre of the Crystalline: It is evident, that this Cone must come from the extreme Point of the Object

Object forming the Picture: To find therefore the Situation of this Point, or, which is the same thing, to find the Magnitude of the Object, nothing is required but to trace back the middle Ray *Px*, in the Line it described before its Incidence on the *Cornea* at *x*.

For this Purpose, having, thro' the Point of Incidence *x*, drawn the Right-line ECF perpendicular to the flat *Cornea*, whose Centre is C; from P let fall upon it the Perpendicular PI, and produce it to M, so as IM may be to PI, as the Sine of Incidence to the Sine of Refraction, that is as 4 to 3; and about the Centre *x*, with the *Radius* *x*P, describing a Circle PBD, draw parallel to the Perpendicular FCE the Line MS cutting the Circumference in S, and join S*x*. This Line S*x* being continued backwards, shall be the Line of the incident Ray, in which Line the extreme Point of the Object must be placed to have its Image painted on the *Retina* at the Point P, when the *Cornea* is so flat as to have its Centre at C; for if SR be let fall perpendicularly on the Line E*x*, this Line SR shall be the Sine of Incidence of the Ray S*x*, the Angle of Incidence being S*x*E; and this Line SR is equal to IM, and consequently in proportion to the Sine of Refraction PI, as 4 to 3.

But, if the *Cornea* be more convex, ſo as to have its Centre at *c*, Q*c*x*Z* will be the Perpendicular to this *Cornea* at the Point of Incidence *x*, and PQ will be the Sine of Refraction; which being produced to T, ſo as QT may be to PQ as 4 to 3; if from T, parallel to QZ, the Line T*r* be drawn cutting the Circumference in *r*, the line *rx* continued backwards, ſhall be the Line of the incident Ray; for *rq*, the Sine of Incidence of the Ray *rx*, is to PQ, the Sine of Refraction, as 4 is to 3; wherefore the extreme Point of the Object muſt now be in the Line *xro*, to have its Picture at P.

In like Manner, if the *Cornea* be yet more convex, and have its Centre at *a*, in the Centre of the Cryſtalline, the Point of the Picture at P will be formed by a Pencil of Rays, whoſe *Axis* is in the right Line P*axp*.

Thus, then, it appears, that the Object A*p*, when the *Cornea* is very convex, appears as large as the Object A*o*, when the *Cornea* is more flat, and as large as the Object AO, when the *Cornea* is yet flatter; for the Magnitude of the Picture, and of the Angle within the Eye ſubtending it, and under which it is ſeen, is the ſame in all the three Caſes.

What I have here ſaid, is not at all inconſiſtent with what I demonſtrated before, of every

every Point of an Object's being ſeen in a right Line drawn perpendicular to the *Retina* at that Point of it where the Image of the Point falls; for all that is here ſaid ſerves only to ſhew, that a ſmaller Object, when the *Cornea* is convex, may make as large a Picture on the *Retina*, as a larger one, when the *Cornea* is more flat, without determining the Poſition of the Lines in which the ſeveral Points of the Object are ſeen: Yet, as the extreme Points of the ſmall Object, when the *Cornea* is convex, are ſeen in the ſame Place with the extreme Points of the larger Object, when the *Cornea* is more flat, by reaſon the Pictures of both coincide in the ſame Place of the *Retina*, it is obvious, that all the other ſimilar Points of both Objects (I mean all the Points that are ſimilar in Poſition) will alſo be ſeen in the ſame Place; and conſequently that the Place in which the ſeveral Points of Objects are ſeen, will be really ſomewhat different from their true Place, according as the Eye is differently formed, tho' this Difference is ſuch as in many Caſes may be neglected without any remarkable Error.

§ 4. Now, ſince we can never be certain, that there are two Perſons in the World who ſee Objects of the ſame Magnitude, becauſe we are never certain that their Eyes are alike, it follows, that we ought never to truſt the Teſtimony

Teſtimony of our Eyes in judging of the abſolute Magnitude of Bodies; and when, as for Inſtance, we ſay, that a Bird is ſmall, we ought not to underſtand it abſolutely ſo; for there is nothing that is great or ſmall in itſelf: Even a Bird is great with reſpect to a Fly; and tho' it be ſmall relatively to our Body, it does not from thence follow, that it is ſo abſolutely, ſince our Body is not an abſolute Rule, according to which other Bodies ought to be meaſured. Our Body itſelf is very ſmall with reſpect to the Earth, and the Earth is very ſmall relatively to the Circle it deſcribes in moving round the Sun, and ſo forth, without End; for we can always imagine Spaces greater and greater *in infinitum*.

We ought not therefore to truſt the Teſtimony of our Eyes in judging what Extenſion is in itſelf; we ought rather to hearken to Reaſon, that teaches us, that we can never determine what the abſolute Magnitude of ſurrounding Bodies is, nor what Idea we ought to have of the Extenſion of a ſquare Foot, or that of our own Body, ſo as that Idea may repreſent the Object ſuch as it is; for Reaſon aſſures us, that the ſmalleſt Body would not be ſmall if alone, ſince it is compoſed of an infinite Number of Parts, of each of which, if God ſhould be pleaſed, he can form a World;

which

which will be but as a Point, when compared with the other Parts taken together, and yet will contain as many Things, tho' leſs in proportion, as this great World in which we live.

§ 5. But you will ſay, Does GOD then deceive us? Has he given us Eyes, which, like Optic Inſtruments, magnify or diminiſh the Objects? I anſwer, GOD never deceives us; but we frequently deceive ourſelves, by judging of Things with too much Precipitation; for we commonly judge, that thoſe Things exiſt of which we have Ideas, and even that the Things themſelves are altogether ſimilar to theſe Ideas; and yet it is certain, that the Objects are often not at all like the Ideas we have of them, and even that they do not ſo much as exiſt.

It by no means follows, that a Thing exiſts, becauſe we have an Idea of it; and yet leſs, that the Thing is altogether like the Idea we have of it. In Fevers, and in Time of Sleep, we often have Ideas of Objects that do not at all exiſt; and the Sun and Moon are only circular Planes of about a Foot in Diameter, if we believe the Teſtimony of our Eyes: It is therefore a Prejudice, that has no Foundation in Reaſon, to believe that we ſee Bodies according to their true Magnitude; for our Eyes are not given us, but for the Preſervation of our

our Bodies, and never make us see what Things are in themselves, but only what they are relatively to our Body, that we may thereby be informed of Things profitable or hurtful to us; they therefore acquit themselves very well of their Duty, in giving us Ideas of Objects that have some remarkable Proportion to our Body; and we deceive ourselves, when we imagine, that our Eyes were given us to inform us what Extension is in itself absolutely considered.

§ 6. But tho' we can never discover what Extension is in itself absolutely considered, yet, by the Assistance of our Eyes, we can, in most Cases, very well discover the relative Magnitude of all visible Objects; as for Instance, we see, that a Foot is twelve Times larger than an Inch, and that a Yard is three Times larger than a Foot, and so of all other Magnitudes that bear any considerable Proportion to that of our Body. But from thence it does not follow, that we do ever see what Things are in themselves, and according to their true and absolute Magnitude. To imagine otherwise, is to imagine that they always appear of the same Magnitude; which, as has been shown above, is a very great Mistake; for little Animals, such as Mites, see Things of a different Magnitude from us; and we ourselves do also receive different Ideas of Extension,

Extenſion, according to the different Magnitude and Figure of the Eye in general, and of its ſeveral Parts in particular. And this is the Reaſon why ſhort-ſighted Perſons ſee Objects differently from others, and why commonly they appear bigger to the Left-eye than to the right. We alſo ſee Objects of different Magnitudes at different Times, according as we imagine them nearer or farther off; as ſhall be explained hereafter.

This much being premiſed, it remains that we now inquire into the Manner, how, by our Eyes, we diſcover the relative Magnitude of Bodies; for what their true and abſolute Magnitude is, we can never be informed of.

§ 7. There are only two Means whereby our Mind is enabled to judge of the Magnitude of Objects. The *1ſt* is, their apparent Magnitude; the *2d*, the Knowledge we have of their Diſtance.

By the apparent Magnitude of an Object, I mean the Magnitude of its Picture painted on the *Retina*; this Magnitude being ſenſible to us, furniſhes our Mind with the firſt Mean of judging of the Magnitude of the Object; for Objects appearing equally far off, are always ſeen greater or ſmaller, according as their Pictures on the *Retina* are greater or ſmaller; and,

and, if their Pictures are equal, the Objects will alſo appear equal.

§ 8. This Magnitude of the Picture depends upon, and is proportionable to the Angle under which the Object is ſeen, that is, the Angle which is formed by the two right Lines drawn from the two Extremes of the Object to the Centre of the Eye, and which is commonly called the *Optic* or *Viſual Angle*. When this Angle is large, the Picture on the *Retina* is large; but when it is ſmall, the Picture is alſo ſmall in proportion.

Thus, if AB (See *Fig.* 20. PLATE III.) be an Object whoſe Picture on the *Retina* is *ab*, the extreme Points of the Object A and B will be ſeen nearly in the Lines *a*A and *b*B, drawn from the extreme Points of the Picture *a* and *b*, thro' C the Centre of the Eye; and theſe Lines *a*A and *b*B, by interſecting each other at C, muſt make the Angles at the Vertex equal; that is, the Angle *aCb* will be equal to the Angle ACB: But the apparent Magnitude, or the Image on the Bottom of the Eye *ab*, is always proportional to the Angle *aCb* ſubtended by it; and therefore muſt alſo be proportional to the equal Angle ACB. But this Angle ACB is the viſual Angle, or the Angle formed by right Lines drawn from the Extremities of the Object to the Centre of the Eye;

Eye; and therefore the apparent Magnitude, or the Image on the *Retina*, will always be porportional to the optic Angle under which the Object is ſeen; whence all Opticians meaſure the apparent Magnitude by this Angle, which they therefore, in their Reaſonings, do always ſubſtitute in the Place of the Image itſelf.

§ 9. From what has been ſaid, we may eaſily ſee, that we can never, from the apparent Magnitude alone, diſcover the Magnitude of the Object; for the Pictures of two Objects may be equal, tho' the one be a hundred Times bigger than the other, provided that their Diſtances from the Centre of the Eye be proportional to their Magnitudes.

Thus, the Objects AB and DF (*Fig.* 20. PLATE III.) have their apparent Magnitudes equal, and yet their true Magnitudes are to each other as their Diſtances from C the Centre of the Eye: For the Triangles ABC, DFC being ſimilar, AB is to DF as AC is to DC.

In like Manner, when any Object, as AB (*Fig.* 21. PLATE III.) is viewed at different Diſtances from the Eye O and P, its apparent Magnitude will increaſe very nearly in the ſame Proportion, as the Diſtance between the Centre of the Eye and the Object decreaſes; and, on the contrary, it will decreaſe in the

ſame Proportion as that Diſtance increaſes; for the Object being at a conſiderable Diſtance from the Eye, the optic Angle AOB, will be to the optic Angle APB, nearly as PB is to OB.

It is therefore evident, that we can never, from the apparent Magnitude alone, make a right Judgment of the Extenſion or Magnitude of Bodies; it is always neceſſary that their Diſtance be alſo known; from both which together, it is very eaſy for us to diſcover the Magnitude of Objects; for, by tracing back the Rays from *a* and *b* (*Fig.* 20.) the extreme Points of the Picture, in the perpendicular Lines *a*A and *b*B; the extreme Points A and B of the Object muſt appear ſomewhere in theſe Lines *a*A and *b*B; and the Diſtance of the Object being at the ſame Time known to us, theſe Points muſt be ſeen in their proper Place A and B, and conſequently the Magnitude of the Object will be eſtimated by the Line AB joining the two extreme Points of the Object.

§ 10. There is yet another Way of explaining how, from the apparent Magnitude and Diſtance, we come to judge of the Magnitude of Objects; it is as follows:

In the Triangles ACB, *a*C*b* (*Fig.* 20.) the Angles at C are equal, being the Angles at the

the *Vertex*; and the Line AB being parallel to the Line *ab*, the Angles *a* and *b* muſt be equal to the Angles A and B, each to each; that is, the Angle *a* is equal to the Angle A, and the Angle *b* is equal to the Angle B: Hence the two Triangles *aCb* and ACB are ſimilar, and therefore their homologous Sides muſt be proportional, that is, the Line *ab*, or the Magnitude of the Picture, muſt be to AB, or the Magnitude of the Object, as *b*C is to BC: But *b*C is the Semidiameter of the Eye, which does not exceed half an Inch, or ſix Lines, and B C is the Diſtance of the Object from the Centre of the Eye; and therefore the apparent Magnitude of Objects, or their Picture on the *Retina*, will be to the Magnitude of the Object itſelf, as about half an Inch, or ſix Lines, is to the Diſtance of the Object from the Centre of the Eye; from which Analogy, the Magnitude of the Object is eaſily diſcovered.

§ 11. The Magnitude of the Object may alſo be determined by this other Method, which is no leſs accurate, and does not ſuppoſe the Semidiameter of the Eye to be known. The Canon is this:

As the *Radius* is to the Tangent of Half the apparent Magnitude ACG (*Fig.* 20.) ſo is the Diſtance C G to the Half of the true Magnitude A G.

This

This Propoſition is ſo plain, that it needs no Proof or Illuſtration; for it is obvious, that, if about the Centre C, with the *Radius* C G, a Circle be deſcribed, the Half of the true Magnitude A G ſhall be the Tangent of Half the apparent Magnitude A C G.

§ 12. By ſuch methods as theſe, our Mind is enabled to exerciſe its natural Geometry in judging of the Magnitude of Objects; neither is it poſſible for us to be miſtaken, unleſs when we are miſtaken in the Judgment we form of the Diſtance; which does indeed frequently happen.

We have a remarkable Example of this in reſpect of the Sun and Moon, which appear greater when near the Horizon than at a greater Height; tho', as is known to Aſtronomers, the Picture of the Sun in the Bottom of the Eye is the ſame in both Caſes, and that of the Moon is leſs when ſhe appears near the Horizon, by reaſon of her greater Diſtance. We cannot indeed judge of the Diſtance in either caſe; but it appears greater near the Horizon, by reaſon of the Interpoſition of the Fields and Part of the Heavens, which make us judge thoſe Bodies, bigger than afterwards when they are more elevated: Whence it is, that when the above mentioned Bodies are viewed thro' a long Tube, this

apparent

apparent Diſtance vaniſhes, as alſo the Magnitude which is deduced from it.

It is ſomewhat ſurprizing, that GASSENDUS, an Author of ſome Fame, ſhould aſcribe this enlarged Appearance of the horizontal Luminaries merely to a Dilatation of the Pupil, which he ſuppoſes to attend the View of celeſtial Objects, near the Horizon (*de apparente Magnitudine Solis humilis et ſublimis, Epiſt.* 1. *Art.* 5.). But this is inconſiſtent with the Principles of Optics, yet this Author is ſo totally ignorant of that Science, as to aſſert, that a dilated Pupil magnifies an Object, for the ſame Reaſon as a convex Glaſs does. (*Ibid. Epiſt.* 2. *Art.* 13.).

§ 13. Another Example of this Kind is the Appearance of parallel Lines and long *Viſtos* of parallel Rows of Trees ſeen by the Eye placed between them at one End of the *Viſto*; for ſuch Lines and *Viſtos* ſeem to converge more and more, as they are further extended from the Eye. Thus the Lines ABC, DEF, (*Fig.* 22. PLATE III.) appear to converge towards the imaginary Line OG, drawn from the Eye O parallel to them.

The Reaſon of this is, becauſe the apparent Magnitudes of their perpendicular Intervals AD, BE, CF, *&c.* are perpetually diminiſhing, while, at the ſame Time, we miſtake their Diſtance, and, by referring them to the

Plan

Plan of the *Horopter*, to which our Eyes are directed, thoſe that are further off than this Plan are judged nearer than they really are; and thoſe that are nearer than this Plan, are judged more diſtant than they really are (as ſhall be explained afterwards in its proper Place); from which Miſtake with reſpect to the Diſtance of thoſe perpendicular Intervals, they will appear ſhorter and ſhorter the further they are from the Eye, and conſequently the parallel Lines will appear to converge more and more continually, till they meet in the Middle.

§ 14. Moſt Authors I have met with, in accounting for this *Phænomenon*, neglect intirely the Conſideration of the apparent Diſtance of thoſe perpendicular Lines, and deduce the *Phænomenon* from their apparent Magnitude alone: But tho' the apparent Magnitude of thoſe Perpendiculars does continually decreaſe in Proportion as their Diſtance from the Eye increaſes; yet, if their Diſtance were known, we would judge rightly of their Magnitude in the Manner above explained: To me therefore it ſeems evident, that this *Phænomenon* depends intirely on the Miſtake we commit with reſpect to the Diſtance of thoſe perpendicular Lines; for, did we judge rightly of their Diſtance, we ſhould alſo judge rightly of their Magnitude, and ſee them to be of equal

equal Lengths, and conſequently the parallel Lines would appear parallel. Hence we may ſee why, when the two parallel Rows of Trees ſtand upon an Aſcent, whereby the more remote Parts appear further off than they really are, by reaſon that the Line meaſuring the Length of the *Viſto* now appears under a greater Angle than when it is horizontal, the Trees in ſuch a Caſe will ſeem to converge leſs; and ſometimes, in place of converging, they will be thought to diverge, as is agreeable to Experience.

§ 15. And, for the ſame Reaſon that a long *Viſto* appears to converge more and more, the further it is extended from the Eye, the remoter Parts of a horizontal Walk, or a long Floor appear to aſcend gradually; and Objects placed upon it, the more remote they are, the higher they appear, till the laſt be ſeen in a level with the Eye: Whereas, the ceiling of a long Gallery appears to deſcend towards a horizontal Line drawn from the Eye of the Spectator: For the ſame Reaſon, the Surface of the Sea, ſeen from an Eminence, ſeems to riſe higher and higher, the further we look; and the upper Parts of high Buildings ſeem to ſtoop or incline forwards over the Eye below, becauſe they ſeem to approach towards a vertical Line, proceeding from the Spectator's Eye; wherefore Statues

a-top

a-top of ſuch Buildings, to appear upright, muſt recline or bend backwards.

§ 16. Another *Phænomenon* of this Kind is, that of a Wind-Mill ſeen at a great Diſtance; for, by taking the neareſt End of the Sail for the moſt remote, we ſometimes Miſtake the Courſe of its circular Motion.

This *Phænomenon* may eaſily be accounted for: For, if a Spectator at O (*Fig.* 23. PLATE III.) ſituated nearly in the Plan of the Sails produced, imagines the furtheſt End A of the Sail AE to be the neareſt, and the real Motion of the Sails be in the Order of the Letters ABCDE; when A is moved to B, and the Line BO is drawn cutting the Circle ABCDE in D; ſince he at firſt imagined the End A to be at E, he will not now conceive it at B, but at D; and ſo will imagine the Courſe of the Motion to be from E to D; which is contrary to the real Motion from A to B.

The Uncertainty we ſometimes find in the Courſe of the Motion of a Branch or Hoop of lighted Candles turned round at a Diſtance, is owing to the ſame Cauſe; and alſo that we miſtake a convex for a concave Surface ſometimes with the naked Eye, but more frequently in viewing Seals and Impreſſions with a convex Glaſs or a double Microſcope.

§ 17.

§ 17. It is also for the same Reason, to wit, a Mistake with respect to the Distance, that, upon coming into a Street in a dark Night, where there is but one Row of Lamps, we often Mistake the Side of the Street they are in. This may be accounted for in this Manner:

Let O (PLATE III. *Fig.* 24.) be the Spectator; A, B, C, D, the Lamps on his Left-hand; A*a*O, B*b*O, C*c*O, D*d*O, the Rays that come to his Eye. Now, if he happens to imagine the nearest Lamp A to be the remotest, suppose at *a;* he will consequently imagine all the rest to be at *a*, *b*, *c*, *d*, in the Situation of a Line extended on his Right-hand; which is contrary to the Situation in which they truly are.

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## CHAP. V.

### *Of the Distance of Objects.*

HAVING explained how we judge of the Extension or Magnitude of Bodies, by comparing their apparent Magnitudes with their Distances, and how we are deceived

in thoſe Judgments, as often as we are deceived with reſpect to the Diſtance; I ſhall now conſider by what Means our Mind, by the Aſſiſtance of our Eyes, is informed of the Diſtance of Objects. This is the fifth *Phænomenon* of Viſion, which now falls naturally to be explained.

§ 1. There are *Six* Things whereby we are enabled to diſcover the Diſtance of Objects, from the Conſideration of which it will eaſily appear how we are ſometimes deceived, and can ſcarce form any Judgment with reſpect to Diſtance, but what is founded on Prejudice and Anticipation.

§ 2. The *firſt* Mean whereby the Mind judgeth of Diſtance, conſiſts in that Diſpoſition of the Eye that is neceſſary for ſeeing diſtinctly at different Diſtances.

We have already demonſtrated, that there can be no diſtinct Viſion, unleſs the Rays of Light, which are ſent from the ſeveral Points of the Object, be, by the Humours of the Eye, refracted, and brought together in ſo many correſponding Points on the *Retina*; and that the ſame Conformation in the Eye is not able to perform this Effect, but muſt be changed by the Contraction of the *Ligamentum Ciliare*, which being ſenſible to us, becauſe it depends upon our Mind which regulates it, will enable us in ſome Meaſure to judge of Diſtances, even

even with one Eye: As for Inſtance, when I view an Object at ſeven Inches Diſtance, I diſtinguiſh its Diſtance by the Diſpoſition of the Eye, which at that Diſtance is not only ſenſible, but in ſome Sort uneaſy; and when the ſame Object is viewed at twenty ſeven Inches Diſtance, the Diſtance is ſtill perceived, becauſe the neceſſary Diſpoſition of the Eye is ſtill ſenſible, tho' no longer uneaſy. And thus you ſee, how, with one Eye alone, we judge of leſſer Diſtances, from the Change which happens in the Conformation of the Eye; but as this Change in the Conformation of the Eye has its Limits, beyond which it cannot go, it can be of no Uſe in aſſiſting us to judge of the Diſtance of Objects placed without the Limits of diſtinct Viſion, which, in my Eyes, about 22 Years ago, reached no further than from ſeven to twenty ſeven Inches. But as the Object does then appear more or leſs confuſed, according as it is more or leſs removed from theſe Limits, this Confuſion ſupplies the Place of the Motion of the Cryſtalline in aiding the Mind to judge of the Diſtance of the Object, it being always eſteemed ſo much the nearer or further off, by how much the Confuſion is greater.

But this Confuſion has its Limits alſo, beyond which it can never extend; for, when an Object is placed at a certain Diſtance from

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the Eye, to which the Breadth of the Pupil bears no ſenſible Proportion, the Rays of Light that come from a Point in the Object, and paſs the Pupil, are ſo little diverging, that they may, in a phyſical, tho' not mathematical Senſe, be looked on as parallel; and therefore the Picture on the *Retina* will not, to Senſe, become more confuſed, tho' the Object be removed to a much greater Diſtance. What this Diſtance is to which the Diameter of the Pupil bears no ſenſible Proportion, Authors are not agreed on, nor ſhall I at preſent take upon me to determine; but, conſidering the Smallneſs of the Pupil, it is obvious, that it cannot reach any far Way; and conſequently this Confuſion in the Appearance of Objects can only aſſiſt us in judging of ſmall Diſtances.

§ 3. The *ſecond* moſt univerſal, and frequently the moſt ſure Mean we have for judging of the Diſtance of Objects, is the Angle made by the optic *Axes* at that Part of the Object on which our Eyes are fixed: For our two Eyes are like two different Stations in Longimetry, by the Aſſiſtance of which Diſtances are taken, as hath been already explained at ſome Length. And this is the Reaſon why thoſe that are blind of one Eye do ſo frequently miſs their Mark in pouring Liquor into a Glaſs, ſnuffing a Candle, and

ſuch

such other Actions as require that the Distance be exactly distinguished; of which Mr. Boyle has given several Instances in his Observations upon the vitiated Sight.

§ 4. Whence we may see, how this Mistake with respect to Distance, when one of the Eyes is lost, may sometimes assist us in making a very judicious and useful Prognostic in the Case of a *Gutta Serena* affecting only one of the Eyes. Every body knows, that, when this Disease is of an old standing, all Attempts towards a Cure are commonly in vain, and to no Purpose; but when the Disease is recent, it often admits of a more favourable Prognostic: But it sometimes happens that the Patient cannot tell at what Time he lost the Sight of his Eye; for when one of the Eyes continues good, he may for a long while not discover that the other is lost; of which Mr. Boyle gives an Instance in his above mentioned Observations on vitiated Sight; for he there tells us, of One who had a Cataract for several Years, without knowing it, tho' others did; for he knew it not, till happening to rub his sound Eye, he was surprised to find himself in the dark. When One therefore has a *Gutta Serena* only in one of his Eyes, he may think that the Eye was only lost, when he made the Discovery of it, tho' it was lost many Years before. On the other Hand, having

having been informed, that one may be blind of one Eye a long while without diſcovering it; and that *Gutta Serenas* are frequently uſhered in by violent Head-achs, he may imagine that the Loſs of Sight, which happened only a Week ago, and which he only diſcovered Yeſterday, is of many Years ſtanding, becauſe at that Time he had a violent Head-ach, and never any Complaint ſince. Thus you ſee what Difficulty there may be in determining the Age of this Diſeaſe; and conſequently what hopes there may be of curing it; but, by inquiring at what Time he firſt became liable to Miſtakes, in all Actions that require that the Diſtance be exactly diſtinguiſhed, as in pouring Liquor into a Glaſs, ſnuffing a Candle, threading a Needle, *&c.* we may diſcover the Age of the Diſeaſe, and thence may be aſſiſted to form a more juſt Prognoſtic with reſpect to its Cure. *

§ 5.

* This Theory was lately of ſome Uſe to me in the Caſe of a young Lady, who conſulted me for a Blindneſs in one of her Eyes; which, from ſeveral Circumſtances, was ſuſpected to have been of a long ſtanding, tho' ſhe had only diſcovered it the Day before. On examining her Eyes, I found that they moved ſimilarly, and that the *Pupils* ſympathized with each other in their Motions. Whence I concluded ſhe had not been blind of that Eye from the Birth. I therefore aſked her, if ſhe was not

§ 5. From what hath been ſaid on this Head, we may alſo ſee whence it comes to paſs, that, when the Eyes are fixed on any Object, the Diſtance of other Objects, that are nearer or further off, cannot be exactly known to us; for, ſince our Eyes are not directed to theſe Objects, we are deprived of this Mean of judging of their Diſtance; and therefore, by referring them to the Plan of the *Horopter*, to which our Eyes are directed, Objects that are further off than this Plan, are judged nearer than they really are, and Objects that are nearer than this Plan, are judged more diſtant than they really are: From which Principle many Fallacies of Viſion, otherwiſe inexplicable, may eaſily be accounted for; of which I have given ſome Inſtances above, and

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not liable to Miſtakes in ſnuffing a Candle, pouring Liquor into a Tea-cup or Glaſs, and if ſhe could thread a Needle as well as ever, or when ſhe firſt obſerved ſuch Defects in her Sight? She owned ſhe was now, and had been for ſeveral Weeks, very ſenſible of theſe Defects; but aſſured me they only happened about twenty Days or a Month ago; and that before that ſhe was not liable to any ſuch Miſtakes, and could thread a Needle as readily as any Body elſe: Whence I concluded, that her Diſeaſe, which proceeded from the Nerve, as the Eye was perfectly clear and tranſparent, and as the Pupil was dilated and without Motion in all Degrees of Light, while the other Eye was kept ſhut; I ſay, I concluded, that the Diſeaſe was at moſt only of about 20 Days or a Month's ſtanding, and might therefore very readily yield to Medicine; which accordingly happened; for, in about ſix Weeks, that Eye became as good as the other, and ſtill continues ſo.

and ſhall here mention only one or two more from Dr. JURIN.

§ 6. This learned Gentleman has told us, that in ſhaving himſelf by a Glaſs hung in a Window, which looks into a Garden, it has ſeveral Times happened to him, that a Fly has ſettled upon the Window near the Glaſs, and in creeping along, has raiſed in him the Idea of a large Bird flying in the Air; and ſometimes that of a Dog or Cat running croſs the Garden, according as the Situation of the Fly, with regard to the Eye, projected its Image either upon the Air or upon the Ground.

The Reaſon of this Appearance may eaſily be deduced from what has been ſaid; for, when the Eyes are fixed upon the Image reflected from the Glaſs, they are ſo adapted, as to ſee that Image diſtinctly in a Place as much beyond the Glaſs, as the Face is before it; and therefore the Fly being much nearer than that Image, and likewiſe being ſeen obliquely, it muſt appear very indiſtinct. It muſt alſo appear a good deal larger than it really is, becauſe we imagine it at a greater Diſtance than it is; and not being able to diſcover its true Diſtance, becauſe our Eyes are not directed to it, we immediately fancy that it is in the Air beyond the Window, or upon the Ground; and being thus deceived as to its Diſtance, we

are

are alſo deceived as to its Magnitude; whence the Animal appears much larger than it is, and moving with a greater Velocity. So true it is, that in the ſuddeneſt Judgments we make, the Idea of greater Diſtance raiſes in us the Idea of an Object of greater Magnitude, and moving with a greater Velocity; the apparent Swiftneſs of its Motion being magnified in the ſame Proportion with the Diameter of its Bulk.

The ſame Author tells us, that, upon uſing a Sort of Fence hung upon his Head, to ſhade his Eyes from the Light of the Candles in reading, a Fly has ſettled upon the Inſide of that Fence, within three or four Inches of his Eyes, and, by creeping along the Edge of it, has ſuddenly raiſed in him the Appearance of a Rat, running along the Floor. This is to be accounted for in the ſame Manner as in the other *Phænomenon*, and is a farther Proof that we cannot judge rightly of the Diſtance, and conſequently of the Magnitude of Objects, unleſs they be in the Plan of the *Horopter*.

§ 7. We are alſo deprived of this Mean of judging of Diſtance, in all great Diſtances, where the Diſtance of our Eyes bears no ſenſible Proportion to the Diſtance of the Object; and therefore it needs be no Surpriſe to us, that in ſuch great Diſtances it ſhould be impoſſible for

us, by this, or any other Method, to judge rightly of the Diſtance; becauſe the Change that happens here to this Angle made at the Object by the optic *Axes* is ſo ſmall, as to be altogether inſenſible. What this Diſtance is, at which we begin to be inſenſible of any Change in this Angle, when the Object is tranſported to a greater Diſtance, is not eaſy to determine: The learned *de* CHALES ſays, we are inſenſible of any Change in it, at all Diſtances greater than 120 Feet; and that any Knowledge we have of greater Diſtances, is not from the Sight alone, but has always ſomething of Reaſoning mixed with it: Whence he concludes, that, when Objects are at a greater Diſtance from us than 120 Feet, we refer them to that Diſtance, and judge of them accordingly. And this is the Reaſon he gives, why the Sun appears only of about a Foot in Diameter; for, being ſeen under an Angle of about 30 Seconds, a Circle of about a Foot Diameter, at the Diſtance of 120 Feet, is ſeen under the ſame Angle, and therefore they appear equal (See *de* CHALES's *Optics*, *Lib.* II. *Prop.* 32.)

§ 8. The *third* Mean for judging of the Diſtance of Objects, conſiſts in their apparent Magnitudes, or the Magnitude of their Image painted upon the *Retina*. The Diameter of theſe Images does always diminiſh in proportion

on as the Diſtance of the Object they repreſent does increaſe; and therefore, from this Change in the Magnitude of the Image, we eaſily judge of the Diſtance of Objects, as often as we are otherwiſe acquainted with the Magnitude of the Objects themſelves. And this is the Reaſon why Painters do always diminiſh the Magnitude of Objects in their Pictures, in proportion as they would have them appear at a greater Diſtance. But, as often as we are ignorant of the real Magnitude of Bodies, we can never, from their apparent Magnitude, or the Magnitude of their Image on the *Retina*, form any Judgment of their Diſtance. And this is one Reaſon why the Stars do all appear at the ſame Diſtance, tho' it is certain that ſome are vaſtly nearer than others: For there are an Infinity of Objects whoſe Diſtance we can never perceive, becauſe we are intirely ignorant of their Magnitude.

§ 9. From this we may ſee, why we are ſo frequently deceived in our Eſtimates of Diſtance, by any extraordinary Magnitudes of Objects ſeen at the End of it; as in travelling towards a large City, or a Caſtle, or a Cathedral Church, or a Mountain larger than ordinary, we think they are nearer than we find them to be upon Trial; for ſince, by Experience, the Ideas of certain Quantities of known

Diſtance

Distance are usually annexed to the apparent Magnitudes of known Objects of a moderate Size, and since the apparent Magnitudes of those larger Objects at a greater Distance are the same as of the smaller at a smaller Distance, it is no Wonder they suggest the usual Idea of smaller Distance annexed to more common Objects; especially because we are ignorant of the Nature of the Country, and of the Inequality in the Ground interposed. And this also is the Reason why Animals, and all small Objects seen in Valleys contiguous to large Mountains appear extraordinary small: For we think the Mountain is nearer to us than if it was smaller; and we should not be surprised at the Smallness of the Neighbouring Animals, if we thought them farther off. And for the same Reason we think they are extraordinary small, when they are placed upon the Top of the Mountain, or upon a large Building, which appear nearer to us than they truly are, because of their extraordinary Magnitude.

§ 10. The *fourth* Thing whereby we judge of the Distance of Objects, is the Force wherewith their Colour acts upon our Eyes: For, if we are assured that two Objects are of a similar and like Colour, and that the one appears more bright and lively than the other,

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we judge, by Experience, that the Object that appears moſt bright, is nearer than the other.

There are ſome who, in explaining this Matter, would have us believe, that the Force wherewith the Colour of Objects ſtrikes our Eyes, muſt decreaſe in a reciprocal duplicate Proportion of their Diſtances, becauſe the Intenſity and Vigour of Light does always decreaſe in that Proportion. That the Intenſity or Vigour of Light does always decreaſe in a reciprocal duplicate Proportion of the Diſtances from the radiant Point, I readily acknowledge; for ſince the Light is diffuſed ſpherically, like Rays drawn from the Centre to the Circumference, its Intenſeneſs at any given Diſtance from its Centre of Activity, will be proportional to the Denſity of its Rays at that Diſtance; and therefore, if A (*Fig.* 25. PLATE III.) be any radiant or viſible Point; and if, ABE, ACF, ADG, *&c.* repreſent the Rays flowing ſpherically therefrom, the Rays which at the Diſtance AB, are diffuſed thro' the ſpherical Surface BCD, at the Diſtance of AE, are diſperſed thro' the whole ſpherical Surface EFG; but the Denſity of any given Quantity of Rays is reciprocally as the Spaces they occupy; that is, if the Surface EFG be double the Surface BCD, the Rays at the Surface BCD, will be twice

twice as thick or dense as the same Rays at the Surface EFG; and if the Surface EFG be triple the Surface BCD, the Rays at BCD will also be three times denser than the same Rays at the Surface EFG; and universally whatever Proportion the Surface EFG has to the Surface BCD, the same Proportion will reciprocally obtain betwixt the Density of the Rays at the Surface BCD and the Surface EFG: But, (as is manifest from ARCHIMEDES *de Sphera et Cylindro*) the Surfaces of Spheres are in a duplicate Proportion of their Diameters or *Radii*; and therefore the Thickness or Density of the Rays at the Distance AB, is to their Density at the Distance AE, in a reciprocal duplicate Proportion of the Semidiameter or Distance AE, to the Semidiameter or Distance AB. But, as has been already said, the Vigour or Intensity of Light in any given Distance is always as the Density of its Rays at that Distance; and therefore the Intensity of Light at any Distance, as AB, will be to its Intenseness at any other Distance, as AE, in a reciprocal duplicate Proportion of the Distance AE to the Distance AB; that is, as the Square of AE is to the Square of AB.

But, tho' the Intensity and Vigour of Light does thus decrease in a reciprocal duplicate Proportion of the Distances from the radiant Point,

Point, it does not from thence follow, that the Force wherewith Objects act upon our Sight, does alſo decreaſe in the ſame Proportion; and that for this obvious Reaſon, *viz.* That as the Intenſity of Light decreaſes by the Diſtance of the Object, ſo does the Magnitude of the Image upon the *Retina* alſo decreaſe in the ſame Proportion; and therefore this Image will be as ſtrong and lively, and will act as powerfully upon the *Retina*, when the Object is at a Diſtance, as when it is near; and conſequently the Object will, at all Diſtances, appear equally clear and luminous, unleſs there be ſome other Cauſe that can make it otherwiſe.

For underſtanding what this Cauſe is, we need only let into a darkened Chamber, thro' a ſmall Hole in the Window-ſhut, a Beam of the Sun's Light: For this Beam being ſeen like a luminous Path in all Poſitions of the Eye, it is evident, that the whole Light does not go forward in its rectilineal Courſe, but that, at all Points of the *Medium* thro' which it paſſes, ſome Part of it is reflected every Way, by Means of which the Beam becomes Viſible; and therefore this ſame Beam, by reaſon of the continual Diminution made in its Light, muſt grow weaker and weaker continually, and that in proportion to the Opacity of the *Medium* thro' which it paſſes. If the Air be pure and

and clear, little Light will be reflected, and more will be transmitted. If it be moist or smoaky, more will be reflected, and less transmitted. But be it never so clear, some Part of the Light will always be reflected or stifled in its Passage; and consequently its Intensity must always decrease in proportion to the Distance of the Object from which it flows.

Seeing then the Intensity and Vigour of Light does thus continually decrease, according as the Distance of the Object increases, it follows, that Objects must always appear less luminous, and more tinged with the Colour of the *Medium* thro' which they are seen, the further they are removed from our Eyes; and therefore, when we are otherwise assured, that two Objects are of the same Colour, if the one appear more bright and lively than the other, we are taught by Experience to conclude, that that which appears most bright is the nearest. And it is for this Reason, that luminous and strongly illustrated Bodies do always appear nearer than they really are. Whence it is easy to see, why a Chamber appears less when its Walls are whitened, and why the Fields and Hills appear less when covered with Snow: For, in these and such like Cases, the Brightness and Strength of Colour makes them seem nearer; from which we conclude, they are smaller: For we always judge of the

the Extension and Magnitude of Bodies, by comparing their apparent Magnitude with their Distance. From this also we may see, why Fire and Flame appear so small when they are seen at a Distance in the Night-time. For the Pupil being then much dilated, more Light will enter the Eye, which, by acting more powerfully on the *Retina*, must make the Object appear much nearer, from which it will be judged smaller.

And as bright and luminous Bodies appear nearer and less than they really are, so, on the contrary, dark Objects, and Objects that are faintly illuminated, do always appear farther off and greater, by reason of the Faintness and Obscurity of their Colour. This is particularly observable, when dark Bodies are seen in the Twilight, which always seem farther off and greater, than when seen in the brighter Light of Day. And it is also for the like Reason, that the apparent Distance and Magnitude of Objects are increased when seen in misty Weather: For much Light being intercepted or scattered irregularly in its Passage thro' the Mist, less of it will enter the Pupil, and consequently it will act less forcibly on the *Retina*; from which the Object will be esteemed at a greater Distance, and bigger than it ought: And indeed, the Deception of Sight arising from this Cause, is

so great, that I have been told, that a distant Sheep has sometimes in a misty Day been mistaken for a Horse.

And this Opacity of the Atmosphere which hinders Part of the Light from coming to the Eye, is also the Reason why the Sun, Moon and Stars, appear very faint when near the Horizon, and brighter continually as they rise higher: For the Tract of Air and Vapours which lies in the Way of the Rays, is longest and thickest near the Horizon, and becomes thinner and shorter as the Objects rise higher, and consequently does less obstruct the Passage of the Rays*. And this to me seems to be one

* M. Bouguer, Professor of Hydrography at *Croisic* found by Experiments that the Light of the Moon is frequently 2000 Times weaker in the Horizon than at the Altitude of 66 Degrees; and that the Proportion of her Lights at the Altitudes of 66 and 19 Degrees, is about 3 to 2. And the Lights of the Sun and Stars must bear the same Proportion to each other at those Heights, which he made Choice of, as being the Meridian Heights of the Sun at the Summer and Winter Solstices in the Latitude of *Croisic*. His Manner of Trial was this: When the Moon was 19 Degrees high, he received her Light perpendicularly upon a white Paper, and also the Light of 4 Candles perpendicularly upon another Paper hard by; then he ordered the Distance of the Candles to be, varied, till he judged their Light upon the Paper to be equal to that of the Moon upon the other Paper; and found the Distance of the Candles from the Paper to be 50 Feet: Then he repeated the same Experiment when the Moon was 66 Degrees high, and found her Light equal to that

one Reaſon why theſe Bodies appear always the bigger the nearer they are to the Horizon: For, ſince they appear fainter, they will alſo appear at a greater Diſtance; from which they will alſo appear bigger for the ſame Reaſon that Objects appear ſo in miſty Weather.

From all which I think we may ſafely conclude, that the apparent Colours of Bodies are very uſeful for us in judging of their Diſtances as often as we are otherwiſe well acquainted with the Intenſity and Vigour of their Colour at any other determined Diſtance. And it is from this Principle that ſkilful Painters do upon the ſame Plane repreſent Objects at different Diſtances, by increaſing or diminiſhing the Intenſeneſs of their Colour, according as they would make them appear nearer or farther off.

It is indeed true, that the Pupil, by its contractile Power, does always proportion itſelf, as much as poſſible, to the Vigour and Strength of Light; from which ſome may think it ſhould be

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that of the ſame Candles at the Diſtance of 41 Feet from the Paper. The Proportion of theſe Lights is therefore as the Square of 50 to the Square of 41, or in round Numbers about 3 to 2. The horizontal Light of the Moon was found the ſame Way, but is ſubject to greater Variations, by paſſing thro' more Vapours. See his *Eſſai dioptrique ſur la Gradation de la Lumiere, pag.* 22.

be impossible for us to judge of the Distance of Objects from their apparent Colour, or the Force wherewith they act upon our Eyes. But to this it is easy to answer, that the Dilatation and Contraction of the Pupil is sensible to us, because it depends on the Motion of the *Uvea* that we feel, which Motion proceeds from the different Force, wherewith the Light acts upon our Eye, which therefore must always be sensible to us; and therefore, tho' the Pupil should, by its Contraction, allow no more Light to pass to the *Retina*, when the Object is near, than when it is farther off, yet we are very sensible of the Intenseness of its Light, because we know that the Pupil is then contracted. And besides, when the Pupil is contracted, we see more distinctly than when it is dilated, by which also we are assisted in judging of the Distances of Objects.

§ 11. The *fifth* Mean for judging of the Distances of Objects, consists in the different Appearance of their small Parts; when these Parts appear distinct, we judge that the Object is near, but when they appear confused, or when they do not at all appear, we judge that it is at a greater Distance.

For understanding this, we must consider, that the Diameters of the Images painted upon the *Retina* are always diminished, according as

as the Diſtance of the Objects they repreſent is increaſed; and therefore any Object may be made to vaniſh, by placing it at ſuch a Diſtance from our Eyes, as to make its Picture inſenſible, becauſe of its Smallneſs; but the ſmaller the Object be, it will ſooner vaniſh: Hence it is, that all the ſmall Parts of an Object are not ſeen at every Diſtance; for the leaſt viſible Part will always be ſmaller or greater, according as the Object itſelf is nearer or farther off. Thus the leaſt Part that is viſible at one Foot Diſtance, will vaniſh at two Feet Diſtance, and the leaſt Part that is viſible at two Feet Diſtance, will become inviſible at three Feet Diſtance, and ſo forth without End. From all which, it is manifeſt, that when the Eye can ſee diſtinctly the ſmall Parts of an Object, it muſt judge that that Object is nearer than any other, whoſe equal Parts are not at all ſeen, or only ſeen confuſedly. Painters are well acquainted with this, who therefore, to repreſent Objects at different Diſtances upon the ſame Plane, do always paint them diſtinct or confuſed in proportion as they would make them appear nearer or farther off; for, when the Picture is confuſed, its ſmall Parts cannot be diſtinctly ſeen, and therefore we judge it at a greater Diſtance than ſuch as have their Parts more diſtinctly painted.

§ 12.

§ 12. The *ſixth* and laſt Mean which we have for judging of the Diſtance of Objects is, That the Eye does not repreſent to our Mind one Object alone, but at the ſame Time it makes us alſo ſee all thoſe that are placed betwixt us and the principal Object whoſe Diſtance we conſider: As for Inſtance, when we look at any diſtant Object, ſuch as a Steeple, we commonly ſee at the ſame Time ſeveral Fields and Houſes bewixt us and it; and therefore, becauſe we judge of the Diſtance of theſe Fields and Houſes, and at the ſame Time ſee the Steeple beyond them, we conclude, that it is removed to a much greater Diſtance, and even that it is every way larger than when it is ſeen alone, without the Interpoſition of any other viſible Object; and yet it is certain, that the Image thereof that is painted upon the *Retina*, is always the ſame in both Caſes, provided that we ſee it from a Place equally diſtant.

Thus you ſee how we judge of the Magnitude of Objects from their apparent Diſtance, and how the Bodies, that we ſee betwixt us and any Object, aſſiſt us in judging of its Diſtance, juſt as by the confuſed Remembrance of all that we have done or ſuffered, and of all the Thoughts we have had, we are enabled to form a Judgment concerning the Extent of our Duration, or, which is the ſame Thing,

of

of the Magnitude or Extent of Time which has passed since we performed any particular Action: For it is these successive Thoughts and Actions which enable our Mind to judge of the past Time, or the Extent of any Part of our Duration; or rather the confused Remembrance of all these successive Thoughts and Actions, is the same Thing with the Judgment of our Duration, as the confused Sight of Fields and other Objects that are betwixt us and the Steeple is the same Thing with the Judgment we have of its Distance.

§ 13. And this affords us another Reason why the Moon appears greater when she rises, than afterwards when she is much elevated above the Horizon; for when she rises, by reason of the Interposition of the Fields, she appears removed to the Distance of several Leagues, *viz.* beyond the sensible Horizon, or that Part of the terraqueous Globe which terminates our Sight; whereas, at a great Height, no Body being interposed betwixt her and us, we don't judge that she is above Half a League distant. But, seeing Objects do always appear smaller or greater, according as we judge them nearer or farther off, it follows, that the Moon must appear greater when near the Horizon, than afterwards when she is much elevated, by reason of the different

Judgments

Judgments we form of her Diſtance in thoſe Caſes.

From what hath been ſaid, it is eaſy to ſee, why Diſtances from the Eye ſeen upon a rough uneven Surface, appear ſhorter than it was perfectly plain. For the Inequalities of the Surface, ſuch as Hills and Holes and Rivers, that lie low and out of Sight, either do not appear, or hinder the Parts from appearing that lie behind them; and ſo the whole apparent Diſtance is diminiſhed by the Parts that do not appear in it. And this is the Reaſon that the Banks of a River appear contiguous to a diſtant Eye when the River is low and not ſeen; and that we are frequently uncertain whether the Objects we ſee are on this or that Side of it.

For the ſame Reaſon, when a Flag or Weather-cock appears above any high Building, the Sight alone, at a moderate Diſtance, cannot diſtinguiſh whether it belongs to that Building or to ſome other behind it. And it has ſometimes happened, that, in the Duſk of the Evening, a red Coat of Arms upon the top of a Gate at the End of a Walk, has been taken for a Brick-houſe in the Fields beyond it; which may proceed from the like Cauſe; for not being able to diſcern the Quantity of Ground interpoſed, we may refer the Object to the brighter Sky in the Horizon,

and

and so think it remoter and consequently larger than it really is.

§ 14. There are then *six Means* which serve our Sight for judging of the Distance of Objects, *viz.* their apparent Magnitude, the Vivacity of their Colour, the Distinction of their smaller Parts, the necessary Conformation of the Eye for seeing distinctly at different Distances, the Direction of their *Axes*, and the Interposition of other Objects betwixt us and the principal Object whose Distance we consider. Of these six Things which serve to make Objects appear near or far off, there are only the three first that Painters can possibly make use of in their Pictures; whence it is, that it is impossible for them perfectly to deceive the Sight. But, in the Decoration of Theatres, where all these six Things are artfully conjoined, one needs not be surprised, if he cannot help being deceived; for, in the Scenes, care is taken to diminish the Magnitude of Objects in proportion as one would make them appear far off, while at the same time they diminish the Vivacity of their Colour, and likeways paint them confusedly, that the smaller Parts may not be seen distinctly: And thus the three first Means for judging of the Distances of Objects are perfectly satisfied. And, for the three last, they represent on different Planes, obliquely placed, and a little removed from each other, the Parts of the same Ob-

ject which they would make appear at different Diſtances, ſuch as, the Pillars of any of the Orders of Architecture; by which means the two Eyes are obliged to change their Direction for ſeeing diſtinctly the different Parts of the Object, whether on the ſame or different Planes. And this Repreſentation of Objects, or the different Parts of the ſame Object on inclined Planes placed at a Diſtance one behind another, does alſo occaſion that Change in the Conformation of our Eyes, by which we likewiſe judge of Diſtances that are within the Limits of diſtinct Viſion; and, when the Object is beyond the fartheſt of theſe Limits, as indeed all the Repreſentations made in the Theatres commonly are, the Degree of Confuſion, ariſing from this Poſition of the Planes, ſupplies the Place of this Change in the Conformation of the Eye in forwarding the Deceit; ſo that all the ſix Means whereby we judge of the Diſtance of Objects are ſatisfied, excepting the laſt; which might a little diſcover the Cheat, were not Care taken to repreſent, according to the ſtricteſt Rules of Perſpective, a Series of Objects lying at different Diſtances, on the inclined and differently removed Planes of which their Scenes are compoſed; ſo that, when we view any of theſe Objects, we cannot help judging them farther off than really they are, becauſe we ſee ſo many

ny other Objects placed betwixt them and our Eyes. And thus you see, how, by Art, all the Means whereby we judge of the Distances of Objects may be satisfied, and we thereby deceived. And what contributes yet further to the Perfection of the Cheat, is the false Light wherewith these Decorations are always illuminated.

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## CHAP. VI.

### *Of the Situation of Objects.*

SECT. 1. THE *Sixth Phænomenon* of Vision, which now falls to be explained, is the Situation of Bodies. This the Mind easily perceives, from the Situation of their Image painted on the *Retina*; for if this Image be in the *Axis* of the Eye, we conclude that the Object is straight before us; if it be on the Left of the *Retina*, we judge that the Object is on the Right-hand; if it be on the superior Part of the *Retina*, we thence perceive that the Object is below; and the same of all other Situations: For we have before demonstrated, that the

the Images of Objects are always inverted upon the *Retina*, and therefore towards whatever Side of the *Axis* of the Eye any Object is situated, its Picture will always fall on the oppoſite Part of the *Retina*. We have alſo demonſtrated, that every Object and Part of an Object is ſeen, not in the *Retina*, but in Right-lines drawn from their Image to the Centre of the Eye, and thence continued outwards; and therefore, becauſe of the Interſection of thoſe Lines at the Centre of the Eye, we muſt neceſſarily perceive that Objects are ſituated towards that Side of the *Axis* of the Eye that is oppoſite to the Place of the *Retina* on which their Image falls.

§ 2. Thus in general, we eaſily judge of the Situation of Objects, from the Situation of their Pictures on the *Retina*; but we can never determine how far they are diſtant from each other, or from the *Axis* of Viſion, that is, how far they are above or below, or on either hand, unleſs we alſo know their Diſtance from the Eye; but this being known, we can judge with ſufficient Exactneſs of the true Situation of Objects, and of all their Parts, by tracing back the Impreſſions they make on the *Retina*, along the above-mentioned Right-lines drawn from that Place of the *Retina* on which their Picture is projected, through the Centre of the Eye;

Eye; for these Lines continued outwards, lead to the Object itself, and the several Parts of it, which must therefore all appear in the Place where they are; whence their Situation will be known to us, as has been fully explained before, to which the Reader may have recourse.

## CHAP. VII.

### *Of the Figure of Objects.*

SECT. 1. THE *Seventh Phænomenon* of Vision, is the Figure of Objects. This, after what hath been said, scarce needs any Explanation; for the Figure of a Body is nothing but the relative Situation of the several Parts of its Surface, that limit or terminate its Extension; some are nearer, others farther off; some are straight before us, others are on the upper, lower, right or left Side; and therefore, to judge of the Figure of Objects, nothing is required, but to judge of the Distance and Situation of their several Parts. But this we have already accounted for; and therefore, without saying any thing further upon

on it, I ſhall paſs to the Conſideration of Mr. MOLYNEUX's ingenious Queſtion, which he propoſed to Mr LOCKE, namely,

§ 2. "Suppoſe a Man born blind, and "now Adult, and taught by his Touch to "diſtinguiſh between a Cube and a Sphere of "the ſame Metal, and nighly of the ſame "Bigneſs, ſo as to tell when he felt one and "the other, which is the Cube, which the "Sphere; ſuppoſe then the Cube and "Sphere placed on a Table, and the Blind-"man to be made to ſee: *Query*, Whe-"ther by his Sight, before he touched them, "he could now diſtinguiſh and tell which is "the Globe, which the Cube.

To this Queſtion, both theſe profound Philoſophers pronounce in the negative, and are of Opinion that the Blind-man would not by Sight alone be able to ſay with Certainty which was the Globe which the Cube; and yet, notwithſtanding the great Deference I have for the Opinion of ſo able Judges, I cannot help thinking that they muſt be miſtaken; for, I have already demonſtrated, that the Judgments we form of the Situation and Diſtance of viſual Objects depend not on Cuſtom and Experience, but on an original, connate and immutable Law, to which our Minds have been ſubjected from the Time they were firſt united to our Bodies; and therefore the blind Perſon, immediately upon receiving his Sight, muſt, by virtue of this

this Law, by his Eyes alone, without any Assistance from his other Senses, immediately judge of the Situation of all the Parts of the Globe and Cube, and, by seeing them in the Place where they are, must receive an Idea of the Figure of those Bodies, from which he will be able to tell which is the Globe, and which the Cube: For the Idea which a blind Man must needs form of a Globe by his Touch, will be this, that it is a Body which is exactly alike on all Sides; for, let him roll it as often as he will between his Hands, he can find no Manner of Difference between the one Side and the other: But this is the very Idea which at first Sight such a Man will form of it by his Eyes, and consequently he must at first Sight know it to be a Globe, and not a Cube.

In like Manner, the Idea which a blind Man, by his Touch, forms of a Cube, must be, that it is a Body which is not alike in every Part of its Surface; for, in one Part, he feels a smooth Flat, in another, a sharp Point of an Angle, and in a third, a long Ridge, which reaches from one Angle to another; and this is the precise Idea, which, upon the first View, such a Man will frame of it by Sight; and therefore, at first Sight, he will know it to be a Cube, and not a Globe.

He

He will not indeed, by Sight alone, be able to tell whether what he ſees will affect the Touch with an Idea of Solidity and Reſiſtance; for what he ſees may, for any Thing he can know by Sight, be like the Image ſeen behind a looking Glaſs, which does not at all affect the Touch; but if the Words *Globe* and *Cube* are underſtood to include nothing but Figure, abſtracted from all other tactile Qualities, he muſt at firſt Sight, by ſeeing all the Parts of the Figure in the Place where they are, know the Globe and the Cube, and be able to diſtinguiſh them by their proper Names.

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## CHAP. VIII.

### *Of the Motion of Objects.*

SECT. 1. THE *laſt Phænomenon* of Viſion which I ſhall conſider, is the Motion of Bodies.

By Motion I do not mean the Force or Moment wherewith a Body is moved, and which may be conſidered as the Cauſe of its Motion. This is indeed frequently meant by the Term *Motion*, and is always as a Rectangle,

or

or Product under the Quantity of Matter and Velocity of the moving Body; but by the Word *Motion* we here underſtand that continual and ſucceſſive Change of Place, whereby the moving Body is brought nearer to, or farther from another Body that is conſidered as abſolutely at Reſt: Motion taken in this Senſe, is ſenſible to the Eye, and therefore deſerves a Place amongſt the *Phænomena* of Viſion.

§ 2. But it is carefully to be obſerved, that our Eyes do never inform us what the Magnitude or Celerity of Motion is, conſidered abſolutely and in itſelf, but only what it is relatively, when compared with ſome other Motion: For we have before demonſtrated, that by our Sight we can never judge of the abſolute Magnitude or Extenſion of Bodies, but only of their relative Magnitude, that is, the Magnitude which they have when compared together: Whence I conclude, that we can never know the abſolute Magnitude or Celerity of their Motions, but only the Proportion that theſe Motions bear to one another; for, ſince we cannot judge of the Celerity wherewith a Body moves, but by the Magnitude of the Space it runs thro', it follows, that we can never judge of the abſolute Celerity of Bodies, by reaſon we are

entirely ignorant of the abſolute Length of that Space.

But this is not all; for tho' we were well aſſured of the abſolute Magnitude of the Space deſcribed by a moving Body, yet even then we could not at all know the abſolute Magnitude or Celerity of its Motion; for the Celerity of Motion includes two Things. The *firſt* is, the Tranſlation of a Body from one Place to another, as from *Edinburgh* to *Leith*; the *ſecond* is, the Time required for that Tranſlation. It is not ſufficient to know exactly, how much Space there is betwixt *Edinburgh* and *Leith*, in order to know if a Man has gone thither with a quick or ſlow Motion: To know this, it is alſo neceſſary to know how much Time he has employed in the Motion; and therefore, ſuppoſing that the Length of the Road were exactly known, yet it is abſolutely impoſſible for us, by our Eyes, to judge rightly of the Celerity of the Motion, becauſe we cannot judge rightly of the Time employed in it.

That we never know the abſolute Extent or Magnitude of Time, needs no Proof; Experience teaches us, that, at certain Times, an Hour appears as long as four, and, on the contrary, at other times, four Hours run inſenſibly: As for Inſtance, when one is elevated with Joy, the Hours do not laſt but a Moment, becauſe

becauſe the Time then paſſes without our thinking of it; but when one is ſunk under a Load of Grief, or ſuffers ſome violent Pain, the Days do laſt whole Years. The Reaſon of which is, that the Mind is then wearied of its Duration, becauſe it is painful and uneaſy to it; for as the Mind then applies itſelf more to the paſſing Time as it flows, it muſt know it better, and thence judge it longer, than during Joy, which makes it as it were ſally out of itſelf, and neglect every thing elſe for to attach itſelf intirely to the Object of its Joy; for, as a Perſon finds a Picture ſo much the larger, that he conſiders with more Attention the ſmalleſt Things therein repreſented, or, as one finds the Head of a Fly very large when he diſtinguiſhes with a Microſcope all the minute Parts of which it is compoſed; ſo, in like Manner, the Mind does always find Duration ſo much the greater, that it conſiders it with more Attention. And I have no doubt, but GOD might have ſo applied our Minds to the ſmall Parts of Duration, by making us have a vaſt Number of Senſations in a very little Time, as thereby an Hour might appear to us ſeveral Ages; for, as there are no Atoms in Bodies, ſo there are no Inſtants in Time; and as the ſmalleſt Particle of Matter is diviſible *in infinitum*; ſo there is no Inſtant of Time ſo ſmall, but ſtill another yet ſmaller may be given

given *in infinitum*; and if the Mind were made attentive to these little Parts of its Duration, by Sensations that leave such Impressions on the Brain, as are necessary for remembring them, there can be little doubt, but it would judge Duration much longer than it now does; for, that we have no certain Knowledge of Duration, considered absolutely and in itself, is evident from the Use of Watches, which we are obliged to consult, to know the Extent of the Time that is passed.

Now, since it is certain, that we can never know the absolute Magnitude of Duration, it follows, that we can never know the absolute Magnitude of Motion; but, because we can easily judge of the relative Magnitude of Times or Durations, by comparing them together, so likewise we can easily judge of the relative Velocities wherewith Bodies are moved; for, as we know that a solar Year is greater than a lunar Year, so likewise we easily discover that a Cannon Bullet has a greater Velocity than a Tortoise: So that, tho' our Eyes do not inform us of the Magnitude of Motion considered absolutely, yet they are not wanting in assisting us to discover pretty exactly its relative Magnitude, that is, the Proportion that one Motion has to another. And it is this alone that is necessary to be known for the

Preservation

Preſervation of our Bodies, for which our Eyes were principally given us.

§ 3. How, by our Eyes, we perceive the relative Motion of Bodies, may be eaſily underſtood from what hath been ſaid, in ſpeaking of their Situation; for, ſince Motion is nothing but a continual and ſucceſſive Change of Situation, we muſt, by the ſame Means whereby we judge of the Situation of Bodies, be alſo enabled to judge of their Motion: As for Inſtance, ſuppoſe, 1*ſtly*, That a Body moves ſtreight to or from our Eyes, in that Caſe we judge of its Motion by the Means whereby we are ſenſible of the continual and ſucceſſive Change in its Diſtance. 2*dly*, When the Body moves tranſverſely in a Plane parallel to our Eyes, we judge of its Motion from the Motion of its Image on the *Retina*, while the Eye is ſuppoſed at reſt; but when the Eye moves, and is continually turned and directed to the moving Body, we are then made ſenſible of its Motion, from that Motion that is neceſſary for keeping our Eyes fixed on the Body: And, *laſtly*, When a Body is moved obliquely, that is, when, in moving tranſverſely, it alſo changes its Diſtance, we then judge of its Motion, not only from the Motion of its Image on the *Retina*, but alſo from our being ſenſible of the continual and ſucceſſive

ſive Change which happens with reſpect to its Diſtance.

§ 4. Thus, in general, the Motion of Objects are made ſenſible to us; and from thence we may eaſily account for moſt of the *Phænomena* with regard to the Motion of Viſibles; ſuch as,

1*mo*, An Object moving very ſwiftly is not ſeen unleſs it be very luminous. Thus a Cannon Ball is not ſeen if it is viewed tranſverſely; but if it be viewed according to the Line it deſcribes, it may be ſeen, becauſe its Picture continues long on the ſame Place of the *Retina*, which therefore receives a more ſenſible Impreſſion from the Object.

2*do*, A live Coal ſwung briſkly round in a Circle, appears a continued Circle of Fire, becauſe the Impreſſions made on the *Retina*, by Light, being of a vibrating, and conſequently of a laſting Nature, do not preſently periſh, but continue till the Coal performs its whole Circuit, and returns again to its former Place.

3*tio*, If two Objects, unequally diſtant from the Eye, move with equal Velocity, the more remote one will appear the ſlower; or if their Celerities be proportional to their Diſtances, they will appear equally ſwift.

4*to*, If two Objects, unequally diſtant from the Eye, move with unequal Velocities in the

the ſame Direction, their apparent Velocities are in a *Ratio* compounded of the direct *Ratio*'s of their true Velocities, and the reciprocal one of their Diſtances from the Eye.

*5to*, A viſible Object moving with any Velocity appears to be at reſt, if the Space deſcribed in the Interval of one Second be imperceptible at the Diſtance of the Eye. Hence it is, that a near Object moving very ſlowly, as the Index of a Clock, or a remote one very ſwiftly, as a Planet, ſeem at reſt.

*6to*, An Object moving with any Degree of Velocity, will appear at reſt, if the Space it runs over in a Second of Time be to its Diſtance from the Eye, as 1 to 1400.

*7mo*, The Eye proceeding ſtraight from one Place to another, a lateral Object not too far off, whether on the right or left, will ſeem to move the contrary Way.

*8vo*, The Eye proceeding ſtreight from one Place to another, and being ſenſible of its Motion, diſtant Objects will ſeem to move the ſame Way, and with the ſame Velocity. Thus, to a Perſon running eaſtwards, the Moon on his right hand, appears to move the ſame Way, and with equal Swiftneſs; for, by reaſon of its Diſtance, its Image continues fixed upon the ſame Place of the *Retina*; from

from whence we imagine that the Object moves along with the Eye.

9*no*, If the Eye and Object move both the ſame Way, only the Eye much ſwifter than the Object, the laſt will appear to go backwards.

10*mo*, If two or more Objects move with the ſame Velocity, and a third remain at reſt, the Moveables will appear fixed, and the Quieſcent in Motion the contrary Way. Thus, Clouds moving very ſwiftly, their Parts ſeem to preſerve their Situation, and the Moon to move the contrary Way.

11*mo*, If the Eye be moved with a great Velocity, lateral Objects at reſt appear to move the contrary Way. Thus to a Perſon ſitting in a Coach, and riding briſkly thro' a Wood, the Trees ſeem to retire the contrary Way; and, to People in a Ship, *&c.* the Shores ſeem to recede.

Moſt of theſe *Phænomena* have been pretty well accounted for by De Chales, Wolfius, and other Mathematicians; and therefore, I have only mentioned them, without enlarging at all upon them. But, before I diſmiſs this Subject, I ſhall endeavour to explain another *Phænomenon* of Motion, which, tho' very common, and well known, yet, ſo far as I know, has not as yet had any Solution given

given to it, that can give the leaſt Satisfaction. It is this:

§ 5. If a Perſon turns ſwiftly round, without changing his Place, all Objects about will ſeem to move round in a Circle the contrary Way; and this Deception continues, not only while the Perſon himſelf moves round, but, which is more ſurpriſing, it alſo continues for ſome time after he ſtops moving, when the Eye, as well as the Objects, are at abſolute Reſt.

Why, when the Eye turns round, Objects appear to move round the contrary Way, is not ſo difficult to explain; for, tho', properly ſpeaking, Motion is not ſeen, as not being in itſelf the immediate Object of Sight, yet, by the Sight, we eaſily know when the Image changes its Place on the *Retina*, and thence conclude, that either the Object, the Eye, or both are moved. But, by the Sight alone, we can never determine how far this Motion belongs to the Object, how far to the Eye, or how far to both. If we imagine the Eye at reſt, we aſcribe the whole Motion to the Object, tho' it be truly at reſt; if we imagine the Object at reſt, we aſcribe the whole Motion to the Eye, tho' it belongs entirely to the Object; and when the Eye is in Motion, tho' we are ſenſible of its Motion, yet if we do not

imagine that it moves ſo ſwiftly as it really does, we aſcribe only a Part of the Motion to the Eye, and the reſt of it we aſcribe to the Object, tho' it be truly at reſt. And this laſt is what happens in the preſent Caſe, when the Eye turns round; for tho' we are ſenſible of the Motion of the Eye, yet we do not apprehend that it moves ſo faſt as it truly does; and therefore the Bodies about appear to move the contrary Way, as is agreeable to Experience.

But the great Difficulty ſtill remains, *viz.* Why, after the Eye ceaſes to move, Objects ſhould for ſome Time ſtill appear to continue in Motion, tho' their Pictures on the *Retina* be truly at reſt, and do not at all change their Place. This, I imagine, proceeds from a Miſtake we are in, with reſpect to the Eye; which, tho' it be abſolutely at reſt, we nevertheleſs conceive it as moving the contrary way to that in which it moved before: From which Miſtake with reſpect to the Motion of the Eye, the Objects at reſt will appear to move the ſame way, which the Eye is imagined to move in, and conſequently will ſeem to continue their Motion for ſome Time after the Eye is at reſt.

But all this may need ſome further Explanation; for which purpoſe, let *abcd* (*Fig.* 26.

PLATE

PLATE III.) be the Eye moving round, according to the Order of the Letters *a*, *b*, *c*, *d*, and let A be an Object at reſt ſeen by that Eye: When the Eye moves from *a* to *b*, if we attend to, and are ſenſible of the Velocity with which it moves, we will attribute the Change of the Situation of the Object intirely to the Motion of the Eye, and will therefore conceive the Object at reſt, as it truly is: But if we are entirely unattentive to the Motion of the Eye, and imagine that it is abſolutely at reſt, the Object A will then ſeem to move the contrary Way, with a Velocity proportional to its Diſtance, ſo as to deſcribe an Arch ſimilar to that deſcribed by the Eye in the ſame time, that is, in the Time the Eye moves round from *a* to *b*, the Object will ſeem to move from A to I. In like manner, when the Eye moves from *a* to *b*, with a Velocity equal to the Line *ab*, if we imagine it does not move ſo ſwiftly, and conceive it to move with a ſmaller Velocity, as *ax*, the Object A will appear to move from A to E, ſo as the Arch AE may be ſimilar to the Arch *bx*. And this I take to be what truly happens in the preſent Caſe, when the Eye turns round; for, tho' we are ſenſible of the Motion of the Eye, yet we do not apprehend that it moves ſo faſt as it really does; and

therefore

therefore the Bodies about appear to move the contrary way, with a Velocity correſponding to what is wanting in the Eſtimate we make of the Eye's Motion.

This being underſtood; we may thence ſee, why, when the Eye ſtops moving, the Objects about ſtill appear to continue their Motion; for, tho' the Eye be then abſolutely at reſt, yet relatively, and with regard to the State it was in before, it is truly in Motion the contrary way; for while the Point *a* is in Motion from *a* to *b*, with the Velocity expreſſed by the Line *ab*, this Point cannot be ſuppoſed to reſt without deſtroying the Motion from *a* to *b*, by a contrary Motion equal to the Line *ba*, or *ad*. But tho' that Motion is actually deſtroyed, by this equal contrary Motion when the Eye reſts, yet, as we imagined that the Point *a* moved only with a Velocity expreſſed by the Line *ax*, we muſt now, when this Point is at Reſt, imagine it to move the contrary Way, with a Velocity equal to *ba*—*ax*, that is, *bx*. But if, when the Eye is abſolutely at reſt, it be imagined to turn round from *b* to *x*, with the Velocity *bx*, all Objects, as A, will appear to move the ſame Way in the Order of the Letters AEI; and conſequently will appear to continue their Motion for ſome Time after the Eye ceaſes to move: And, what

may

may forward this Deception the more, is, that we have not been accuſtomed to ſee Objects moving round in a Circle ſtop all at once; whence we may the more readily imagine, that our Eye moves the ſame Way, to keep Pace with the ſuppoſed Motion of the Objects.

Theſe are the principal *Phænomena* of Viſion; in explaining which, I have already tranſgreſſed the Limits I firſt perſcribed to myſelf: And therefore, tho' there are many others of leſs Note, which might eaſily be accounted for from the ſame Principles; yet we muſt not now enter upon them, partly, becauſe theſe already explained are ſufficient for underſtanding the Diſeaſes of the Eye, and the Means whereby they may be cured, for which all that has been yet ſaid, is chiefly intended only as a *Lemma*; and partly, becauſe ſome of the reſt will more naturally fall to be explained in treating of thoſe Diſeaſes.

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## CONCLUSION.

THUS I have finiſhed the firſt Part of my Deſign, which was to explain the Phyſiology of the Eye; in which I have omitted nothing

nothing either neceſſary or uſeful, or curious and entertaining, that our deſigned Brevity could eaſily admit of. I have examined the Structure and Uſe of its external Parts, and thence deduced the Neceſſity of their different Conformations in different Animals. I have inquired into the Globe or Body of the Eye itſelf; and, for the better underſtanding its beautiful OEconomy, I have conſidered theſe ſix Things, 1*mo*, Its Situation in the Body; 2*do*, Its Connection with the Orbits in which it is placed; 3*tio*, Its Form; which is either ſpherical, as in Man, or ſpheroidal, as in ſeveral other Creatures; 4*to*, Its Number; which in Man is always two; but greater in ſome other Animals; 5*to*, Its Motions, which are wanting in ſome Animals; and *laſtly*, Its Fabrick and Compoſition; than which nothing can be more beautiful or noble; every Part, however different in different Animals, being always ſuch as beſt contributes to the Perfection of the whole. After this I have explained the Nature and chief Properties of Light, and from thence, and the known Fabrick of the Eye, I have deduced not only the true Manner of Viſion, and the Uſe of the ſeveral Parts of this Organ, but alſo have accounted for the Neceſſity of its different Conformations in different Animals; and have ſhewn its Structure and Diſpoſition to be always

always ſuch as is beſt fitted to their Neceſſities of Life, and their Manner of Living. And *laſtly*, I have, from the above eſtabliſhed Principles, accounted for the chief *Phænomena* of Viſion. From all which, every body may ſee, what a noble Piece of Geometry is manifeſted in the Fabric of the Eye, and the Manner of Viſion. There is not one Part of the whole Body, that diſcovers more Art and Deſign, than this ſmall Organ: All its Parts are ſo excellently well contrived, ſo elegantly formed and nicely adjuſted, that none can deny it to be an Organ as magnificent and curious, as the Senſe is uſeful and entertaining. Surely it cannot be ſaid, without betraying the greateſt Ignorance, as well as Impiety, that the Eye was formed without Skill in Optics, or the Ear without the Knowledge of Sounds.

Of what Uſe this Theory may be for underſtanding the Diſeaſes of the Eye, and the Method proper for curing them, is too obvious to need to be inſiſted on: For want of ſuch a Theory, the Diſeaſes of the Eye have in all Ages been thought to have ſomething very intricate in their Nature, and to require a Method of Cure quite different from all other Diſeaſes: Whence, as HERODOTUS tells us, the ancient *Egyptians* had Perſons ſet apart for treating theſe Diſeaſes, who were not to meddle

meddle with any other; and even yet, which is very ſtrange, and much to be regretted, notwithſtanding the great Diſcoveries in Anatomy and Optics, their Cure is frequently committed to Pretenders to Secrets, and ignorant Empyrics, who call themſelves *Oculiſts*; but, being entirely ignorant of the Principles of Medicine, and particularly of the OEconomy of the Eye, the Uſe of its Parts, and the Manner of Viſion, they ought never to be truſted with the Cure of ſuch a tender and delicate Organ, wherein the leaſt Miſtake may be of the greateſt Conſequence; of which we daily meet with but too many Inſtances, when it is too late to help them. But the Diſeaſes of the Eye have nothing intricate in their Nature; neither does their Cure depend on any other Principles, than thoſe commonly employed in other Diſeaſes, provided only due Regard be had to the Nature of the Eye, and the Uſe of its ſeveral Parts. And this ought the more to be here inculcated, becauſe ſome of our ableſt Phyſicians have not yet left off talking of Specific Medicines, as if there were ſome ſuch, that are ſpecifically appropriated to the Diſeaſes of this Organ; whereas in fact, there is no ſuch Thing: All Medicines for the Eyes operate the ſame Way as in other Diſeaſes; whence the ſpecious Title of *Specifics* ought always to be laid aſide,

aſide, as ſerving for nothing, but to nouriſh and cloak Ignorance, and the Method of Cure ought to be directed according to the general Indications taken from the preternatural State of the Solids and Fluids of the diſeaſed Part. For the Body of Man is nothing but a curious Machine, whoſe Actions or Functions are the neceſſary Conſequences of its Structure: It is compoſed of Solids and Fluids, which, ſo long as they abide in their natural State, all the Functions are regularly performed. But, on the contrary, when they are any way vitiated, then the Functions are leſed, or, which is the ſame Thing, a Diſeaſe enſues.

The Function of the Eye is Viſion, and whatever hurts the Sight, is called a Diſeaſe: So that, to cure any Diſeaſe in the Eye, nothing is required but to reſtore that natural State and Condition to its Parts and Humours, from which perfect Viſion does proceed.

The Conditions required for perfect Viſion are indeed very numerous; as may be gathered from what has been ſaid above, and therefore the Diſeaſes of this Organ, or the Want of any one or more of theſe Conditions, muſt alſo be very numerous. To explain theſe Diſeaſes in a rational Manner, and agreeable to the Principles I have laid

down, and to point out a Method of Cure founded on Reaſon and Experience, is what I ſhould now proceed to; but being heartily wearied with what I have already done, the Humour of writing will hold out no longer; and therefore I muſt delay this Part of my Deſign till ſome other Occaſion, when I may be more at leiſure, and more in the Humour of writing than I am at preſent, after the Fatigue I have had in compiling the above Theory.

*F I N I S.*

## ERRATA. Vol. II.

Pag. 41. line 2. *For* $\frac{RD}{RXD}$, *read* $\frac{RD}{R+D}$,

p. 46. l. 29. *dele* it.
p. 125. l. 15. *after* and E, *add* and.
p. 161. l. 23. *dele* the.
p. 165. l. 20. *For* affected, *read* effected.
p. 312. l. 28. *For* Situaon, *read* Situation.
p. 331. l. 14. *After* Kind, *add* of.
p. 365. l. 15. *For* leaſt, *read* laſt.
p. 367. l. 13. *For* longer, *read* larger.
p. 431. l. 19. *after* Sounds, *add*, DEUS enim ſine Dominio, Prodentia, et Cauſis finalibus, nihil aliud eſt quam FATUM et NATURA. NEWTON *Princip. Schol. general. ſub fin.*

# VOL. II PLATE I.

Fig. 1.

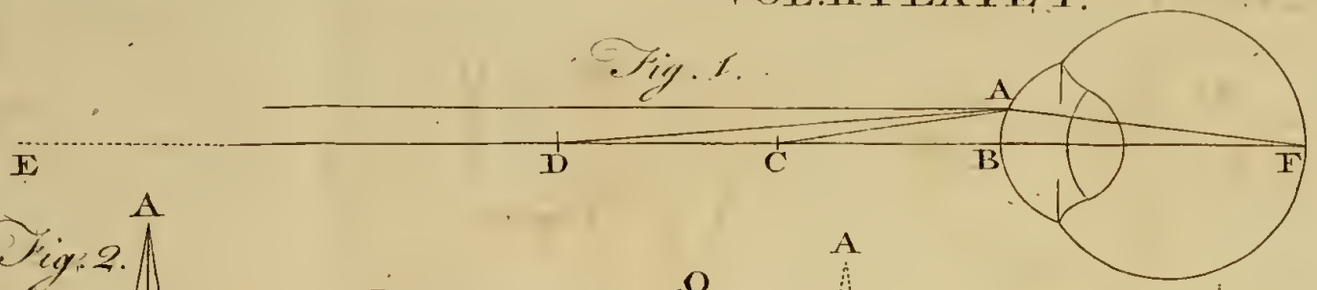



Fig. 2.

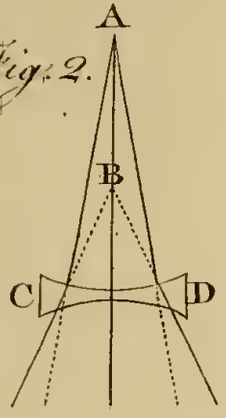
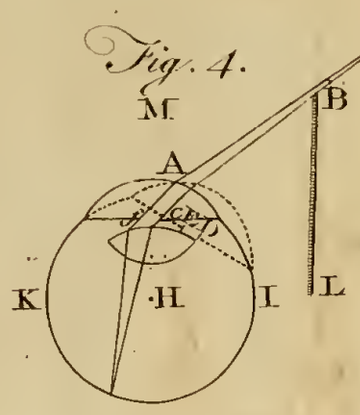



Fig. 4.

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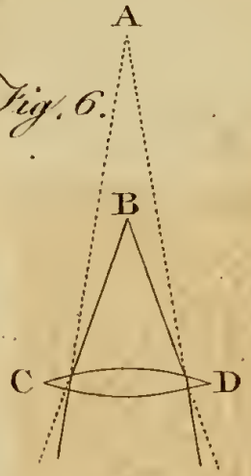


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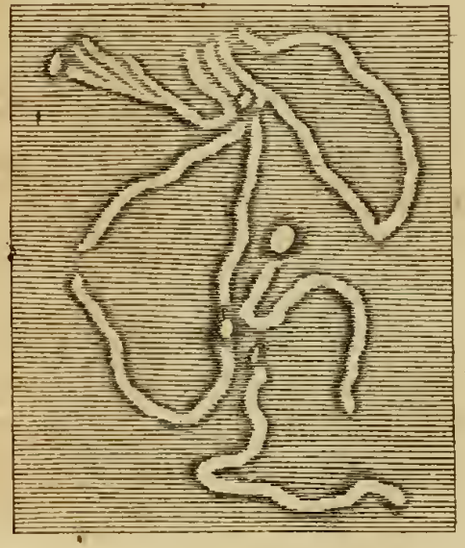

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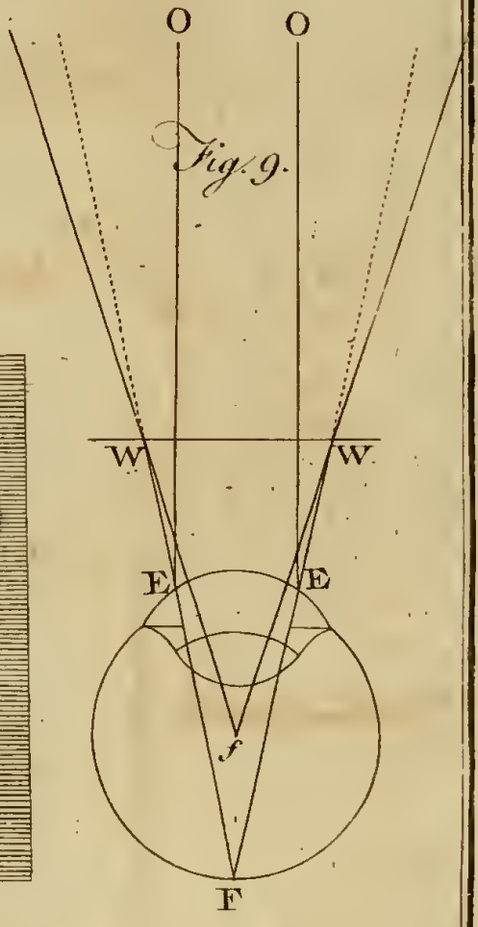



Fig. 3.

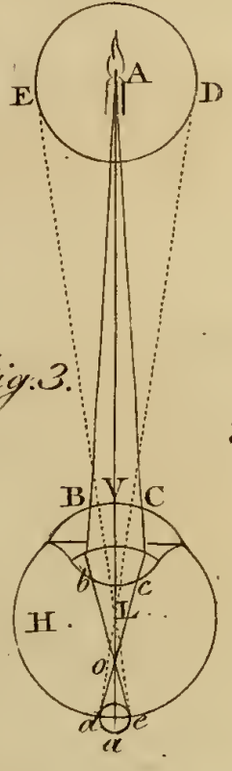
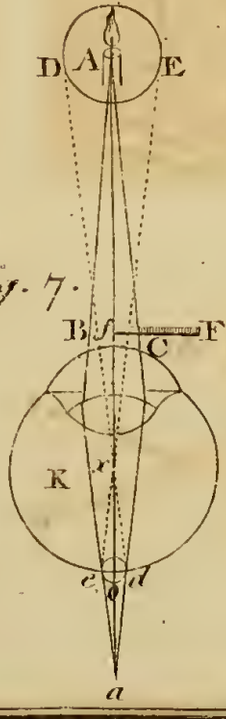



Fig. 5.

Fig. 7.

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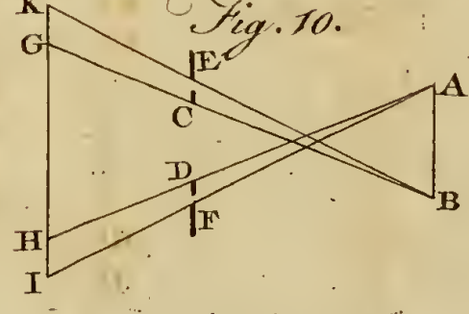


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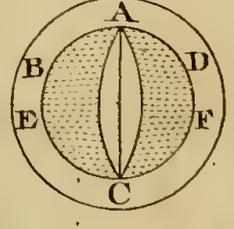

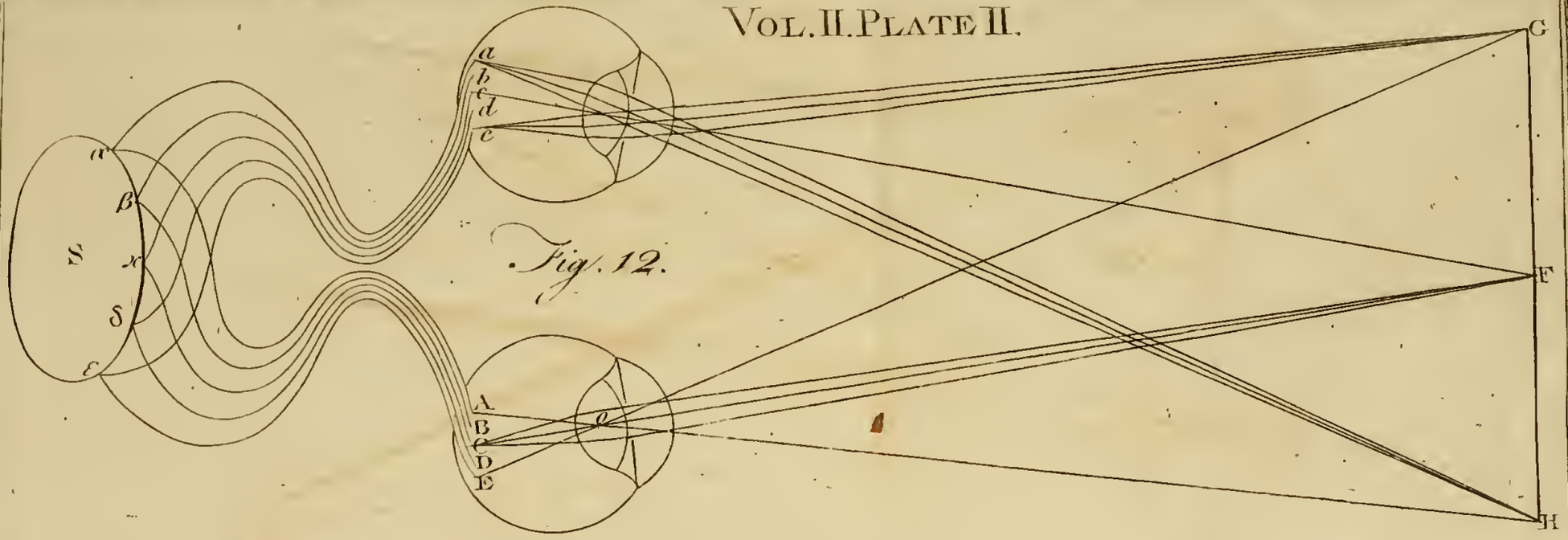


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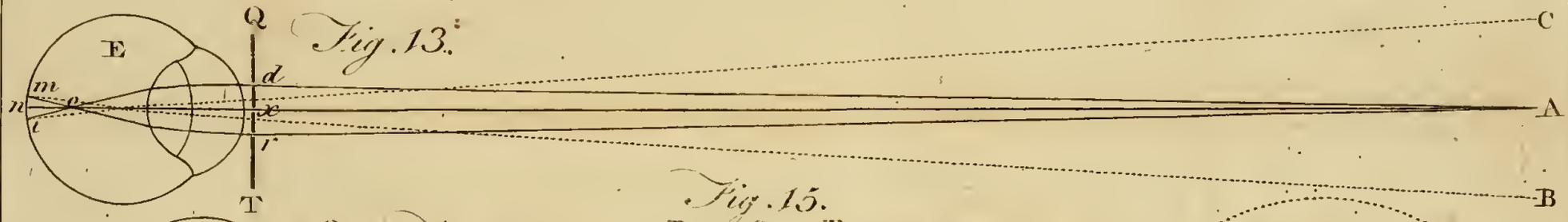


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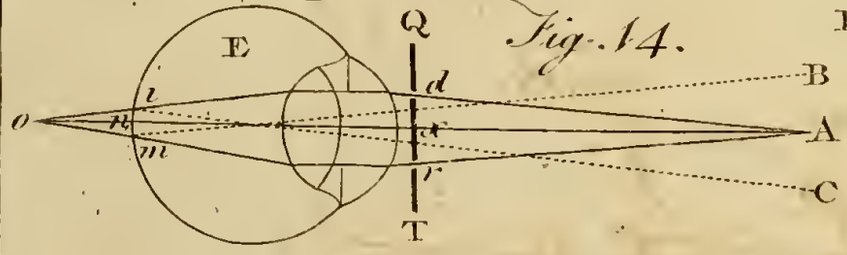


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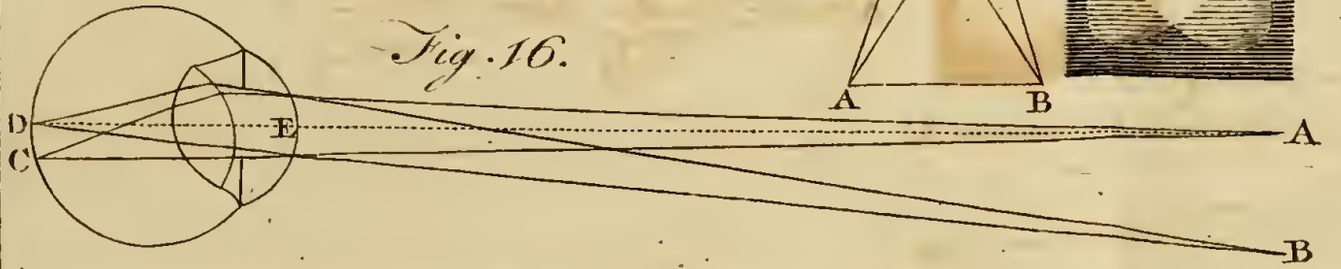
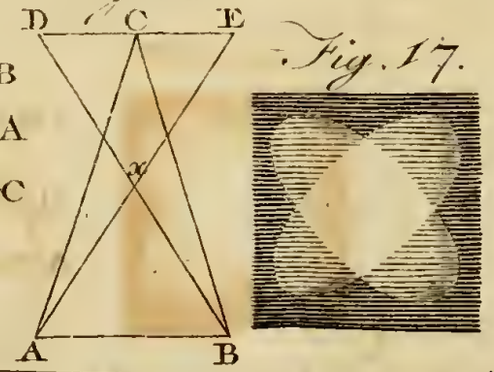



Fig. 16.

Fig. 15.



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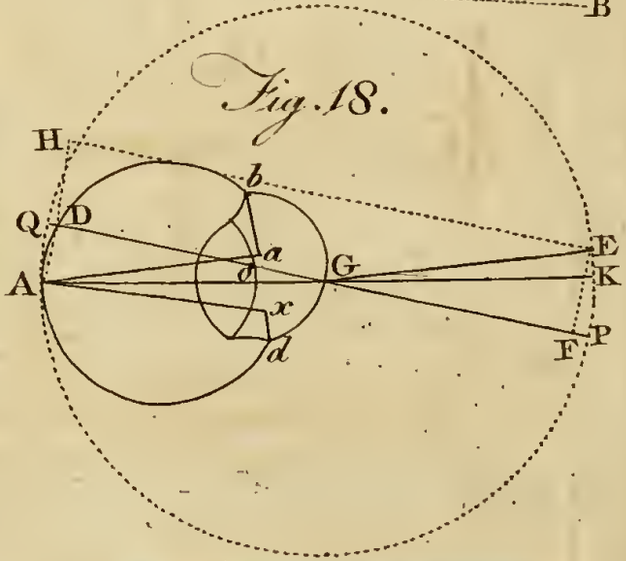
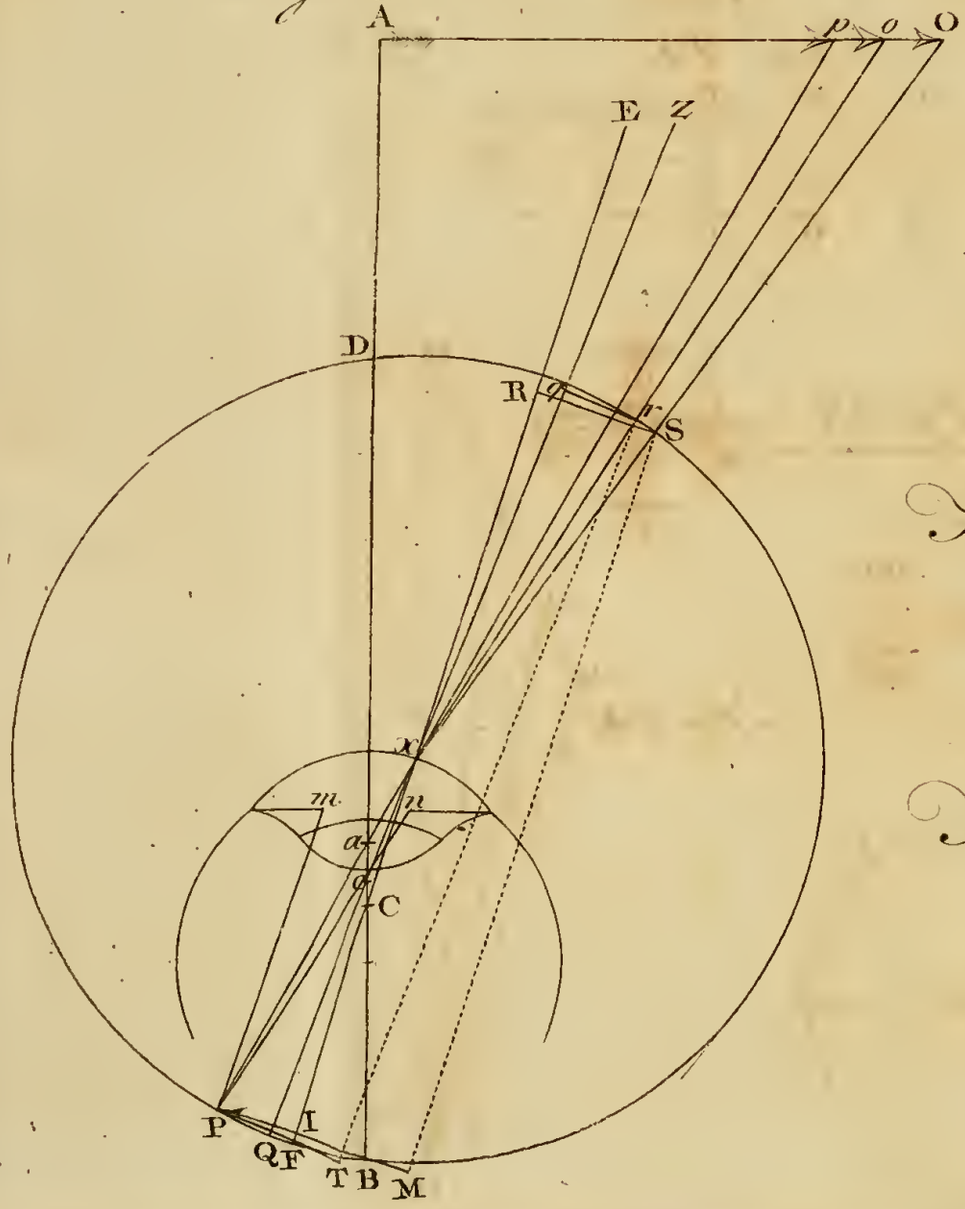



Fig. 18.

# Vol. II Plate III.

Fig. 19.

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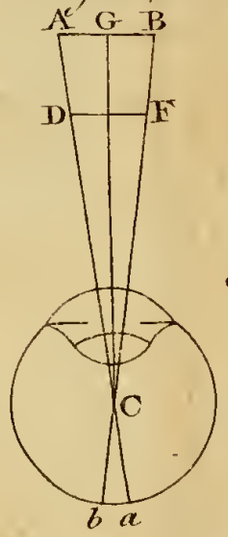


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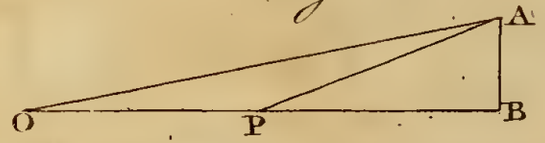


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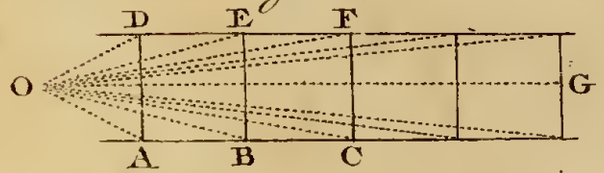


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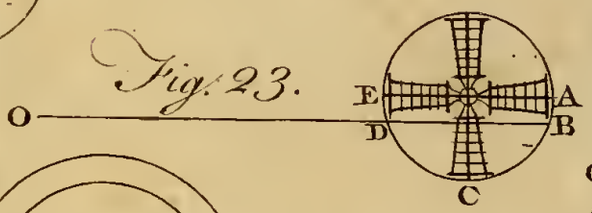


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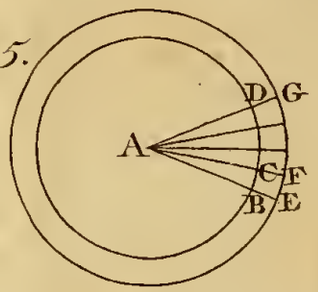


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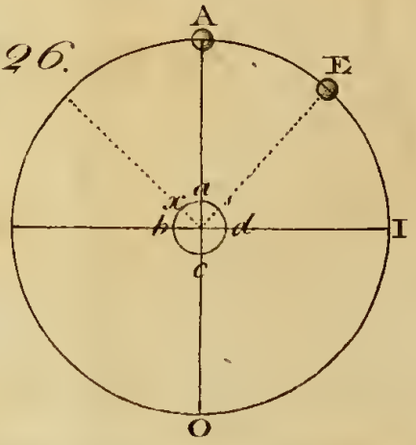


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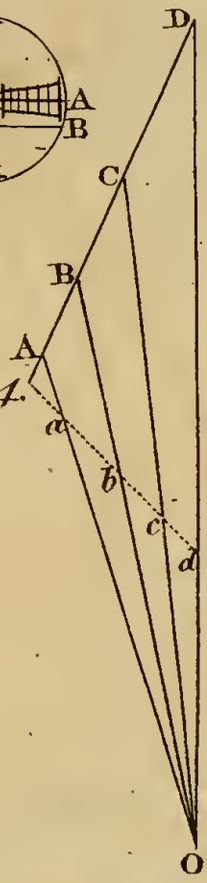

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